IDA

INSTITUTE FOR DEFENSE ANALYSES

Deterrence Effects and Peru's Force-Down/Shoot-Down Policy: Lessons Learned for Counter-Cocaine Interdiction Operations

Robert W. Anthony
Barry D. Crane, Project Leader
Stephen F. Hanson

April 2000

Approved for public release; distribution unlimited.

IDA Paper P-3472

Log: H 99-000873

This work was conducted under contract DASW01 98 C 0067, Task BB-9-1494, for the Office of the Under Secretary of Defense/Policy – Drug Enforcement Policy and Support. The publication of this IDA document does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that Agency.

PREFACE

This document was prepared by the Institute for Defense Analyses (IDA) for the Office of the Secretary of Defense, Assistant Secretary of Defense/Special Operations and Low Intensity Conflict, Office of Drug Enforcement Policy and Support. In addition, the United States Coast Guard Office of Law Enforcement supported the research into examining the thresholds for deterrence and the trafficker responses from operations designed to deter[1] criminal behavior. The objective of this effort was to summarize the results of a 10-year air campaign in Peru to deter and stop the trafficking of coca base to Colombia where it is converted to cocaine prior to transshipment to its ultimate destination, U.S. consumers. The authors would like to express their appreciation to Dr. A. Rex Rivolo for the previous work he did underlying the main results of Chapter V, and Mr. Samir Soneji for his time series analysis work in progress that also contributed to Chapter V.

The IDA Technical Review Committee was chaired by Mr. Thomas P. Christie and consisted of Dr. Gary C. Comfort, Dr. Arthur Fries, Dr. David R. Graham, Gen William W. Momyer (USAF, Ret.), Dr. Catherine W. Warner, and Dr. Steve Warner.

1 Current research has focused on counterdrug operations and criminal violations of U.S. fishing economic zones. Future research is planned to study USCG illegal immigration.

INSTITUTE FOR DEFENSE ANALYSES

IDA Paper P-3472

Deterrence Effects and Peru's Force-Down/Shoot-Down Policy: Lessons Learned for Counter-Cocaine Interdiction Operations

Robert W. Anthony
Barry D. Crane, Project Leader
Stephen F. Hanson

PREFACE

This document was prepared by the Institute for Defense Analyses (IDA) for the Office of the Secretary of Defense, Assistant Secretary of Defense/Special Operations and Low Intensity Conflict, Office of Drug Enforcement Policy and Support. In addition, the United States Coast Guard Office of Law Enforcement supported the research into examining the thresholds for deterrence and the trafficker responses from operations designed to deter[1] criminal behavior. The objective of this effort was to summarize the results of a 10-year air campaign in Peru to deter and stop the trafficking of coca base to Colombia were it is converted to cocaine prior to transshipment to its ultimate destination, U.S. consumers. The authors would like to express their appreciation to Dr. A. Rex Rivolo for the previous work he did underlying the main results of Chapter V, and Mr. Samir Soneji for his time series analysis work in progress that also contributed to Chapter V.

The IDA Technical Review Committee was chaired by Mr. Thomas P. Christie and consisted of Dr. Gary C. Comfort, Dr. Arthur Fries, Dr. David R. Graham, Gen William W. Momyer (USAF, Ret.), Dr. Catherine W. Warner, and Dr. Steve Warner.

---

1 Current research has focused on counterdrug operations and criminal violations of U.S. fishing economic zones. Future research is planned to study USCG illegal immigration.

DETERRENCE EFFECTS AND PERU'S FORCE-DOWN/SHOOT-DOWN POLICY:

Lessons Learned For Counter-Cocaine Interdiction Operations

Table of Contents

List of Figures

List of Tables

EXECUTIVE SUMMARY

This paper summarizes the results of a 10-year air campaign in Peru to stop the trafficking of coca base to Colombia where it is converted to cocaine prior to transshipment to consumer nations abroad. Between 1989 and 1995, three only moderately successful operations had seldom interdicted more than 2.5 percent of the known trafficker flights. Although this interdiction rate was sufficient to greatly reduce farmers' prices for coca base, it was generally insufficient to deter or significantly interrupt the transport of coca base to Colombia. Then in 1995, the U.S. agreed to new rules of engagement – the force-down/shoot-down policy – in which Peruvian Air Force interceptors, with U.S. intelligence, detection, and monitoring support, could shoot down trafficker aircraft if they failed to heed signals to land for inspection. With only a few interceptors, the Peruvians achieved a remarkable degree of success. From March through November, air interdiction rates averaging 13 percent deterred another 64 percent of trafficker flights. After this catastrophic, non-linear collapse of the coca base air bridge, and with the consequent loss of access to Colombian buyers, coca base prices in Peru fell from three times the cost of production to only two-thirds of those costs. Five months later, street prices for cocaine in the U.S. rose by 40 percent and stayed there for several months. More importantly, both U.S. street purity and positive testing rates for casual users dropped and remained approximately 15 percent below the levels established before the collapse of the Peruvian air bridge.[1] Sustained interdiction rates of 7 to 12 percent continue to deter air trafficking to less than 10 percent of its pre-1995 levels.

The key sources of quantitative data for our analyses are: consistently-reported air traffic and interdiction losses in Peru; potential cocaine production as determined from satellite surveys of cultivation; time series of coca commodity prices and production cost estimates in Peru; price, purity, and transaction quantity from purchases of cocaine products within the United States; and extensive commercial laboratory data on positive test rates for persons in the U.S. work force. In addition, interviews with

---

1 While not the subject of this paper, current operations throughout 1999 have pushed both purity and positive test rates among casual users down another 15 percent.

smugglers incarcerated in federal penitentiaries, the literature on risk perception, and transit-zone and Peruvian interdiction operations have supported our development of a mathematical model of the psychology of deterrence. This model explains how interdicting only a few percent of the air traffickers causes the great majority to quit. Numerous trips to the Andean countries and extensive source-zone interviews, reports, and primary sources collected over several years also support our findings about the effectiveness of air interdiction, and essentially rule out alternative explanations of the collapse of the Peruvian coca business.

Our key findings are the result of five distinct analyses that, taken together, tell a consistent story concerning the efficacy of source-zone interdiction as a valuable element of a balanced counter-cocaine policy:

1. To avoid government law enforcement and to grow the most productive variety coca in its natural environment, illicit farming necessarily locates in remote regions with poor transportation infrastructure. Dependence on ground and river transportation for essential imported bulk commodities as well as the need for access to market information and skills causes coca cultivation to concentrate. For example, in 1997, the total land area of high-density cultivation zones within all Andean producer countries was less than 14,000 square kilometers (equivalent to an area 74 by 74 miles), yet this area accounted for over 59 percent of all illicit coca cultivation. Rather than causing dispersion or expansion of cultivation, increased interdiction pressure in Peru, Bolivia, and the Guaviare in Colombia has led traffickers to attempt to replace lost cultivation with plantings within a few high-density safe-haven zones of Colombia.

2. Transportation limitations and security considerations virtually compel traffickers to depend on air transportation to carry coca base to cocaine laboratories or packaged cocaine to transshipment points. The concentration of coca farming areas combined with concentration of the major cocaine laboratory complexes compresses air transport routes into compact geographic areas vulnerable to detection, monitoring, and air interdiction operations. Even at the peak of production and air trafficking in Peru, only about 60 flights per month to Colombia were needed to carry 80 percent of all coca destined for U.S. consumers. It is no wonder that these air trafficking routes have proven to be an inherent structural vulnerability of the cocaine business.

3. Interdictors can and must use coca business indicators to evaluate the effectiveness of their operations. Indicators such as changes in base prices in production regions provide actionable intelligence on whether to sustain or modify an ongoing operation. Otherwise, for example, the interdictors cannot distinguish between smugglers avoiding detection or adopting alternative means versus a cessation of activity that truly damages the cocaine business. Conversely, the three moderately successful air

interdiction operations before the 1995 collapse each caused coca base prices to drop 30 to 50 percent in less than 3 months even though most traffickers continued to fly. Following the collapse in 1995 of the air bridge to Colombia, prices dropped 75 percent in 4 months and remained there until the end of the year. This and other price drops in Peru were accompanied by even larger security cost increases for traffickers because of bribes and compensation for the few remaining pilots willing to take the risks of flying. It took until late 1999, with a more than 66 percent shrinkage in total cultivation, before the residual transportation leakage to a variety of markets, most of them new, was sufficient to restore base prices to more than subsistence levels.

4. Deterrence amplifies the effect of a modest number of interdictions by discouraging the great majority of air trafficker pilots from flying; thus, a relatively low level of air interdiction can virtually deny traffickers this essential mode of transport. For example, given the threat of lethal consequences, interdicting only somewhat more than 3 percent of the *potential* trafficker flights necessary to carry all available coca base was sufficient to deter 64 of the smuggler pilots from flying. Because most pilots were deterred, 3 percent of potential flights averaged 13 percent of actual flights, a very intimidating interdiction rate for those who continued to fly. Once the air bridge collapsed, interdicting even less than 3 percent of potential flights continues to thwart 85 to 90 percent of the potential air traffic.

5. Data on transaction prices and quantities of illicit coca products, from farmgate to U.S. streets, show comparable markups from one trafficking level to the next. Lack of trust and competition between successive levels of middlemen-traffickers, who apparently balance risks against profits in the same manner, can explain the equal markups at each of the several levels. Compounding markups cause price increases in the source-zone to be amplified all the way up to street buyers in the United States. For example, the U.S. street price index has repeatedly risen about 30 percent 4 to 5 months after a major source-zone interdiction operation. Even excluding the operation with the greatest impact on source-zone prices, major operations cause at least a 30 percent or more price *decline* for coca base prices in Peru due to loss of Colombian buyers. This translates into approximately an 18¢ per gram price decrease in Peru required mostly to cover increases in smuggler fees and bribes. Although we do not have extensive price data from Colombia, we do know that Colombian price increases caused by shortages of Peruvian base could not have been many times greater than the price drops in Peru. We expect that price increases in Colombia were actually less than the decreases in Peru. From this, we can estimate that the impact of a source-zone interdiction operation causes a comparable increase on the Colombian side of the air bridge. Thus, an approximately 18¢ source-zone increase corresponds to about an $18 per gram increase in the U.S. street price index – a factor of 100 multiplier generated by the markup dynamics of the cocaine distribution chain.

Many of our research results have already been used to plan and guide operations for the United States Interdiction Coordinator and have been verified several times during subsequent operations and assessments.[2] Fundamental lessons from the Peruvian air interdiction operations should apply to ongoing operations in Colombia. Of course, Columbian interdiction forces need intelligence about air traffickers, coca business data, and government support comparable to what was provided in Peru. Given this support, the principal operational lessons are:

- That under interdiction pressure coca cultivation and processing into cocaine must concentrate for efficiency.
- That air transport into and out of the cocaine laboratories is an inherent vulnerability.
- That deterrence leverage allows a small force to exert catastrophic damage to air transport if it can exceed the deterrence threshold of about a 3 percent interdiction rate if there are lethal consequences.
- That the combination of air and other transport interdictions have the potential to remove most if not all of the profitability from large-scale, source-zone illicit coca business.

Lacking profit, farmers abandon fields, and we would expect that those in other locations would be discouraged from attempting to replace that cultivation unless they believe they can avoid the same interdiction vulnerability.

---

2 In addition to the collapse of the air bridge and attacks on major laboratory complexes in Colombia, interdiction of the go-fast smuggling lanes in the Western Caribbean and current operations have corroborated our research findings on the structure of the cocaine business and deterrence from interdiction operations. The deterrence model also applies quantitatively to the U.S. Coast Guard enforcement of restrictions in U.S. fisheries. See IDA Document D-2381, *Fisheries Law Enforcement: Assessment of Deterrence*, December 1999.

SUMMARY

The purpose of this paper is to review and analyze the counterdrug deterrence operations executed during the 1990's against the major air trafficking routes from Peru to Colombia. Our first objective is to compile and present the qualitative and quantitative evidence about those operations and what happened to drug trafficking and coca cultivation in Peru as a consequence. We will explain how a few Peruvian fighter planes were able to completely disrupt and deter most of the drug transportation from Peru to Colombia, and we will mathematically model the underlying deterrence mechanism that made this possible. We will also describe in detail how the collapse of the air bridge to Colombia caused a market collapse and severe contraction of the illicit coca business in Peru. The loss of Peruvian sources led Colombian traffickers to cultivate coca locally, thereby concentrating worldwide production into a much more compact area that is even more vulnerable to follow-on air interdiction operations.

Our second objective is to analyze quantitatively the cocaine business from farmgate to U.S. streets and characterize the impact of source-zone interdiction operations on cocaine price, purity, and rates of casual use in the United States.

Our third objective is to identify the common misconceptions about the effectiveness of source-zone interdiction, and present the evidence that corrects these misconceptions.

Our final objective is to extract lessons from the Peruvian experience and the analysis of the cocaine business and discuss how these can be applied to future counter-cocaine operations in Colombia as well as in other source- or transit-zone areas. Specifically, we will explain why source-zone transportation, especially air transport, is an inherent vulnerability or "choke point" of the coca business. We will also explain why sufficient interdiction against transportation can reduce the profitability of illicit coca production to the degree that licit business and democratic government can replace the current lawlessness in the coca growing regions.

This summary provides a self-contained recapitulation of the entire report, with some explanation of the empirical support for our principal findings. The main body goes into greater depth describing our information sources, methods of analysis, and findings and observations. Section E of the Introduction (Chapter I) summarizes the content of each subsequent chapter.

A. CONDENSED STORY OF THE PERUVIAN AIR BRIDGE COLLAPSE

In December 1994, a Presidential Finding approved United States Government (USG) detection and monitoring support to the Government of Peru's force-down/shoot-down interdiction of coca trafficker flights from Peru to Colombia. The U.S. determined that Peru complied with international and U.S. rules for identification and warning procedures prior to forcing trafficker aircraft down. With resumed USG detection and monitoring (D&M) support, the Peruvian Air Force (FAP) interdicted at least eight coca trafficker aircraft in March 1995 alone and, on average over the next 8 months, interdicted more than 13 percent of all trafficker flights. This high rate of loss deterred another 64 percent of trafficker flights. Because this air bridge had been transporting most of the coca base production of Peru, the combination of interdiction and deterrence crippled Peru's illicit coca market. As early as April 1995, a glut of excess coca base had accumulated, and, because the farmers in the growing areas could not find buyers, coca base prices in Peru plummeted to below production costs. By August, cocaine prices on U.S. streets had risen 40 percent and, according to SmithKline Beecham Clinical Laboratories (SBCL), the positive testing rate (indirectly indicating casual use) dropped by about 15 percent. By 1999, after 4 years of sustained air interdiction, Peruvian coca farmers had abandoned 66 percent of their illicit coca fields.[1] Thus, military style interdiction operations caused a *structural failure* at a critical step for the cocaine industry – the supply of coca base from its Peruvian source. Colombian traffickers have been replacing in Colombia the loss of Peruvian sources, and after 4 years of expanding their cultivation, they have barely maintained a constant level of

---

1 In comparison to historical levels of coca cultivation in Peru, 17,000 ha, the reduction of excess illicit cultivation from 1995 to 1999 was approximately 81 percent. That is, (115,300 – 38,700) ÷ (115,300 –17,000) = 78 percent.

production.[2] However, the now highly concentrated cultivation regions in Colombia should be even more vulnerable to air interdiction than the dispersed pattern of 1995.

During our visits to Peru in 1999, we learned that all of the principal counterdrug organizations in Lima have by now attributed the drop in coca base prices and the abandonment of the fields to the interdiction of the air bridge to Colombia. Alternative development programs run by the U.S. Agency for International Development (USAID) and the United Nations Drug Control Program (UNDCP) in Peru depend upon interdiction keeping coca prices low so that alternative crops can compete. Even the coca eradication program conducted on Peruvian Government land for which squatters' identities are unknown depends upon low prices. Whenever prices rise to highly profitable levels, there is great incentive to return to growing coca, and coca farmers begin booby trapping their fields and firing at the eradication teams, who then leave the area.

B. END-TO-END VIEW OF THE COCAINE BUSINESS

Considering marijuana as only mildly addictive, cocaine and its derivatives are the most widely used illicit highly addictive drug in the United States.[3] The psychotropically active chemical in cocaine is an alkaloid, methylbenzoylepgonine ($C_{17}H_{21}NO_4$). It is extracted from the leaf of the coca plant by a multi-step refinement process and then distributed through a chain of middlemen until it is sold to users in the United States, Europe, and elsewhere.

1. Farmgate-to-Consumer Flow of Cocaine

Figure 1 shows the steps of the business as a flow diagram tracing the movement of illicit coca from source-country cultivation to consumer-country end-user. From the

---

2 The Crime and Narcotic Center of the CIA (CNC) estimates of potential HCl production for Peru, Colombia, and Bolivia described in Chapter I show that the loss of Peruvian production was being replaced by the expansion in Colombia. However, there are large uncertainties on Colombian HCl productive capacity due to cultivation of a different variety of coca and higher processing efficiencies than Peru, which caused the CNC to revise Colombian estimates upward by a factor of 2.8.

3 Cocaine hydrochloride (HCl) and its various derivatives such as "crack" are the most prevalent illicit drugs, other than cannabis, available in the United States and, in Europe, behind only cannabis and amphetamine-type stimulants (ATS) (Ref. 1, pp. 91-95).

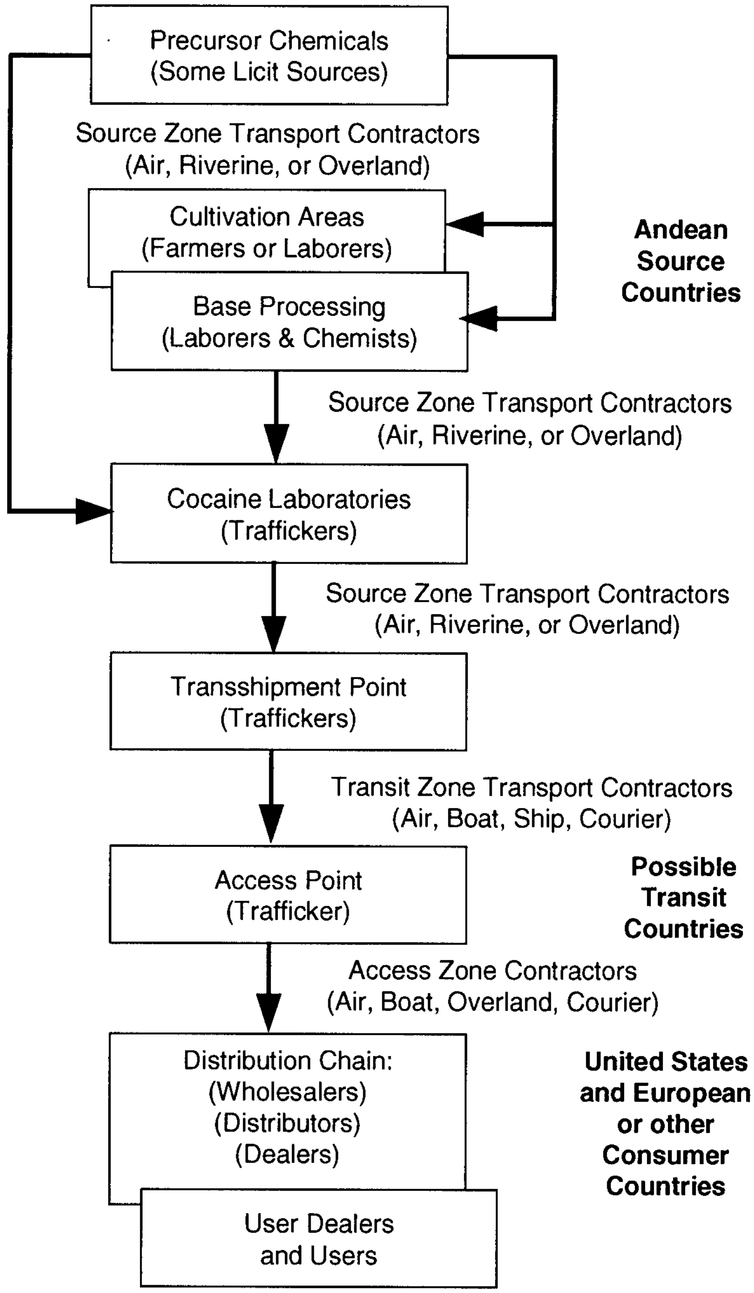


Figure 1. Flow Diagram for the Cocaine Business

many farmers or agricultural workers growing coca leaves on down to the cocaine laboratories, the flows progressively concentrate into larger quantities. After being processed into cocaine, the remainder of the distribution steps consists of smuggling and breaking down the quantities until they are sold to end-users in about one gram quantities. Small contractors perform the smuggling transport steps, while larger and well financed trafficker organizations own the drugs and arrange for the smuggling. Although the source country traffickers deal in very large quantities and transaction revenues, the bulk of the illicit money spent on cocaine remains within the distribution chain inside the United States.[4]

2. Brief History of the Coca Market

Although the United States led the world with a large cocaine epidemic in the 1970s and 1980s, its peak is past, and now the U.S. accounts for only about one-third of worldwide consumption.[5] The demand for cocaine in the U.S. has financed a wave of corruption and lawlessness in the remote growing areas of the Andean nations of Bolivia, Peru, and Colombia because of the very high prices for coca relative to other local crops. During the early 1990s, Peru displaced Bolivia and Colombia as the principal source country for growing illicit coca although Colombia remained the dominant refiner and distributor of that cocaine into the U.S. In the mid-1990s, after air interdiction virtually cut off Peruvian supply to Colombian labs, Colombian traffickers greatly expanded local cultivation of higher-yield "Colombian coca" to replace their lost sources. Meanwhile, counterdrug operations led to a severe decline in the quality of Bolivian cocaine to the degree that the bulk of it was no longer salable in Europe; Bolivian coca now principally supplies Brazilian consumers. Peruvian traffickers have moved in to fill the void in the European market left by the Bolivians and, in combination with some residual trafficking

---

4 We show later that HCl has achieved only 3 to 4 percent of its street price by the time it is smuggled out of Colombia (see Summary Figure 4 and Chapter I). Assuming that even half of the cocaine is delivered to customers implies that over 90 percent of all cocaine revenues are generated in the United States.

5 UNODCCP prevalences scaled by country populations (Ref. 1) would imply U.S. consumption was only one-quarter of world consumption; however, the UNODCCP claims that because of reporting variations among nations, U.S. consumption is more likely one-third of the world total.

to Colombia, have arrested the collapse of Peru's coca market.[6] Thus, as the center of gravity of counter-cocaine operations in the Andean countries shifts to Colombia, we expect that lessons from the Peruvian operations described in this report will assist in operations there as well as with continued reduction of the remaining coca markets in Peru and Bolivia.

3. Coca Cultivation Regions

Most Peruvian and Bolivian coca farmers grow the more productive "upland" coca in Andean Mountain valleys or in areas along the elevated western margins of the Amazon Basin. These regions are shown in Figure 2 in darker shades of green, with darker colors representing greater densities of cultivation. The red arrow indicates the most direct air bridge from Peru's Huallaga Valley to Colombia. The Cuzco region in Peru and the Yungas in Bolivia supply the government sanctioned licit monopoly organizations in their respective countries. This licit production supplies leaves for chewing, coca tea, and exports for pharmaceuticals and flavorings.

Some Colombians cultivate the less productive "lowland" coca within the Amazon Basin itself, especially in the Guaviare region. However, this region continues to decline relative to the newly expanded growing areas of Putumayo and Caqueta. An aggressive aerial spraying program against the Guaviare, and introduction of the more productive "Colombian" variety of coca in the Putumayo and Caqueta regions contribute to this shift. (Two other small areas in northern Colombia, San Lucas and Notre de Santander, are not shown in Figure 2.)

C. KEY FINDINGS

Operational experience from Peru during the period 1989 to 1998 illustrates the degree of vulnerability of the illicit cocaine business to air interdiction. It also illustrates how an Andean nation's modest air force can, with USG assistance, exploit that vulnerability to greatly reduce the scale of illicit coca business in their country. Five questions lead us through the logic that explains why these operations were successful.

---

6 The DEA in Bolivia and Peru shared these findings with us during trips in 1998 and 1999. Also, price increases for Peruvian coca base show that there is sufficient transport to support their greatly reduced production capacity.

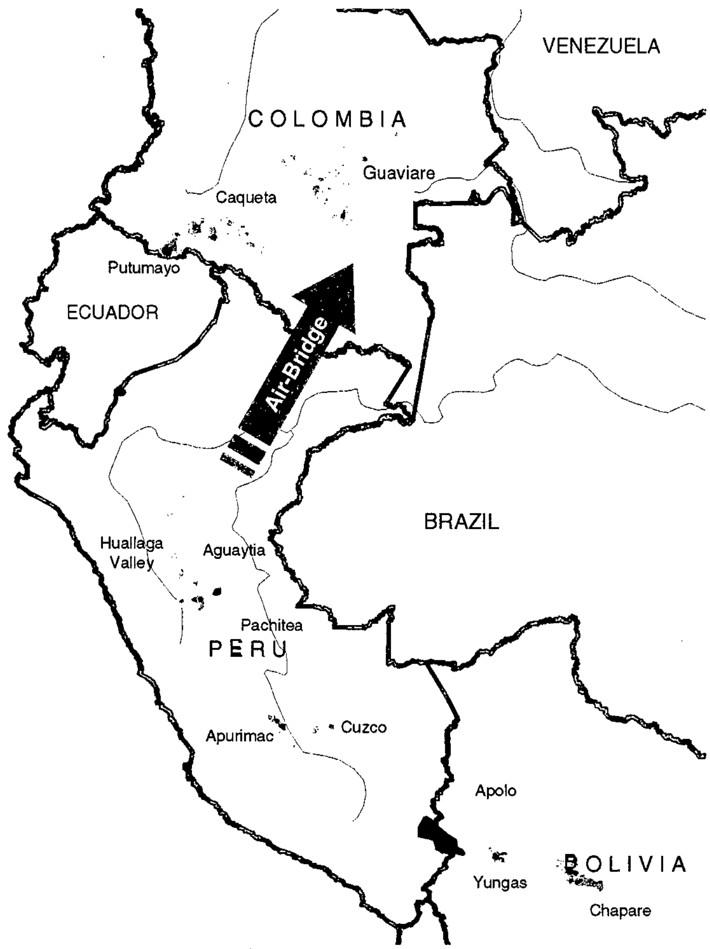


Figure 2. Coca Growing Regions of the Andean Countries in 1997

The answers to these questions introduce the five principal analyses making up the core of this report.

- Why do coca growing regions concentrate into a small portion of the land available for coca cultivation? Ground and river transportation limitations in remote and necessarily lawless growing regions cause cultivation to concentrate in all coca-growing countries. After 1995, air interdiction pressures actually increased concentration in all of those countries. This finding partially addresses our first objective, Colombia's rapid and concentrated expansion of replacement cultivation. The detailed analysis is found in Chapter II.
- Why are the air bridges from growing regions to cocaine laboratories or from cocaine laboratories to transshipment zones inherent vulnerabilities of the cocaine business? Transportation limitations and security considerations

compel traffickers to depend heavily on air transport to carry coca base to cocaine laboratories or packaged cocaine to transshipment points. The concentration of growing regions and major laboratory complexes compresses this air transport into compact geographic areas vulnerable to detection, monitoring, and interdiction.[7] This finding partially addresses our first objective. Our detailed analysis in Chapter I explains why transport modes to and from cocaine labs are choke points, and Chapter II explains why an air bridge is essential, and thus inherently vulnerable.

- Why is it important to monitor indicators of the illicit coca business to determine the relative success of an operation, initially in the source zone and later on the streets the United States? Interdiction forces need coca business indicators, such as base prices in producing regions, to evaluate the effectiveness of their operations and to determine whether to sustain or modify their operations. Otherwise, the interdiction forces cannot know whether the absence of visible air traffic means that traffickers found another route and means, or whether the illicit coca business is truly being diminished. This finding partially addresses our first objective, and our detailed analysis in Chapter III proves that interdiction against the air bridge was the principal cause of damage to the illicit coca market in Peru.
- Why does the interdiction of a small percentage of all air traffickers effectively block most of the flights over the traffickers' air bridge? Once the traffickers' threshold of acceptable risk is crossed, deterrence amplifies the effect of a modest number of interdictions by discouraging the great majority of trafficker pilots from flying. Thus, a relatively low level of air interdiction can virtually deny traffickers this essential mode of transport. This finding also addresses our first objective, and our detailed analysis in Chapter IV shows how our deterrence model of interdiction works.
- Why does a major source-zone interdiction operation cause significant damage to cocaine markets all the way to the streets of the United States? Lack of trust as well as competition among the many levels of middlemen-traffickers in the illicit cocaine business apparently leads to an equal balance of risks against profit markups at each of the several levels. This causes price increases in the source-zone to be amplified all the way up to street buyers in the United States. This finding addresses our second objective, and our detailed analysis in Chapter V shows that source-zone interdiction operations

---

7 Although the CNC revised the Colombian cocaine production estimates upward in 1999, this does not affect our findings that were based on cultivation estimates, which were not revised.

damaged the cocaine business by raising U.S. street prices, lowering street purity, and reducing casual usage.

Results from these principal analyses show that the evidence refutes each of four common misconceptions about the effectiveness of source-zone interdiction thereby addressing our third objective. Finally, we will use the lessons learned from Peru and source-zone interdiction and deterrence to comment on the options for attacking the cocaine business in Colombia, thereby addressing our final objective.

D. COMMON MISCONCEPTIONS

The empirical evidence analyzed in this report gives results counter to four common misconceptions about illicit coca markets and source-zone interdiction operations. The following four misconceptions, expressed as assumptions, concerning source-zone interdiction were first articulated in the mid-1980s and have been commonly accepted by most analysts of the cocaine industry well into the 1990s:

- The taxation assumption asserts that all interdictions in the source zone consist of eradication of coca plants or seizure of coca products and related materials and, therefore, these losses merely tax the traffickers with additional overhead costs (Ref. 2, p. 301; Ref. 3, pp. 92-93).
- The expansion assumption asserts that traffickers can always cultivate more coca either in established or new regions to replace losses to interdiction and law enforcement. Furthermore, this cultivation will be sufficient to satisfy all U.S. demand and, implicitly, European and worldwide demand as well (Ref. 2, p. 298; Ref. 3, pp. 92-93).
- The additive cost market assumption asserts that even if source-zone operations cause source-zone prices to increase by a significant fraction of their former levels, this would not have much impact on the illicit drug business because source-zone costs are a very small fraction of the ultimate street price of the drug (Ref. 2, p. 290; Ref, 3, p. 86).
- The near-equilibrium market adaptation assumption asserts that all forms of drug enforcement in the source zone are absorbed by the adaptive mechanisms of competitive market dynamics, which overcomes these disruptions by readjusting flows and prices to a new and implicitly viable market equilibrium (Ref, 2, p. 296; Ref. 3, pp. 92-93).

If true, these assumptions would imply that source-zone interdiction is a poor investment of counterdrug resources, and in some cases counterproductive.[8] These assumptions leave policymakers with only incremental options that harass one or another component of the illicit cocaine business. Applying only incremental pressure to basic trafficker activities, however, would leave intact all but one of the common assumptions; thus, the assumptions would become a self-fulfilling prophecy.[9]

However, the evidence presented in this report does not support these assumptions – in each case, the reverse is true. But simply knowing that these assumptions are not necessarily true will not assure success for source-zone counterdrug operations. As we will see, the essential distinction between our findings and those implied by the above assumptions lies in the type and focus of counterdrug actions as well as their pace and scope. Our findings confirm that military-type operations against structural vulnerabilities of the cocaine business, applied with sufficient force, shock, and sustained follow-through, can cause a sudden collapse from which traffickers cannot readily recover. Once diminished to a lower scale and profitability, we believe that the residual source-zone coca markets become amenable to several endgame strategies. For example, replacement of coca with alternative crops, renewed government control over national territory, and police law enforcement in growing areas jointly act to restore the licit economy and legitimate social order.

E. FIVE ANALYSES SUPPORT OUR FINDINGS

We now summarize the five principal analyses and associated findings making up the core of this report.

---

8 As late as 1996, the evidence for the effectiveness of interdiction described in this report was still not recognized. "The evidence, while based on a paucity of hard data, is very compelling: cocaine producers rapidly adapt to the pressures of source country programs.... Some analysis indicates that one dollar spent on source country interdiction provides only about 32 cents in benefits" (Ref. 3, p. 258). The evidence and analysis in this report show that the most vulnerable choke points of the cocaine business are in the source-zone, and that interdiction against these vulnerabilities causes extensive and lasting damage. Previous analyses focused on seizures and eradication, but never considered effective action against choke points, their non-linear effects, and the resultant disruption from a near-equilibrium state to a chaotic one.

9 Later in this summary, we will show that the evidence does not support the *additive cost market assumption* even if counterdrug operations relied only on gradual harassment.

1. Transportation Limitations Concentrate Coca Cultivation

Although there are large areas suitable to coca cultivation, transportation constraints and interdiction pressures, when causing low prices, compress the bulk of cultivation into very compact and dense zones that are even more vulnerable to transportation interdiction.

a. Forces for Concentration

Concentration in response to pressure may seem counter-intuitive, but a review of the forces for concentration make this observed outcome seem more plausible. An illicit agricultural activity needs to operate in inaccessible areas isolated from government influence, which implies that the illicit growers do not benefit from a developed transportation infrastructure. This, in combination with the rugged terrain and heavily forested highland regions where the productive coca varieties grow, sharply curtails overland travel. Further, the need for access to supplies, labor, and market information requires frequent contact with a network of other growers and traffickers. While river transport is adequate for heavy and inexpensive supplies, it is a slow and dangerous means for transporting very high value refined coca products or cash for illegal transactions.

b. Forces for Dispersion

The only significant example of dispersion of coca cultivation followed the opening of the Santa Lucia Base (SLB) airstrip in 1990 and, soon afterward, the outbreak of the fungus Fusarium Oxysporum, which devastated the Upper Huallaga Valley coca crop in 1991. Driven also by the desire to avoid fees extorted by the Peruvian guerrilla group Sendero Luminoso, or "Shining Path," many coca farmers relocated to the central or lower Huallaga Valley or to neighboring Aguaytia and Pachitea Regions. However, once again, the bulk of the production in these new regions concentrated into a few dense zones.

c. Travel Distances in the Apurimac Valley

Our analysis of detailed maps of every field, town, and river in the Apurimac Region enabled us to verify the theoretical prediction that transportation limits

geographic distribution.[10] Farmers and their laborers carry coca leaf an average of 2.4 kilometers to get close to the nearest river, where water is available to produce coca base. Traffickers transport the base to one of 10 airfields along the 90-kilometer stretch of the Apurimac River, a 15 to 25 kilometer journey. Smuggler aircraft must travel about 1,600 kilometers to reach cocaine laboratories in Columbia.

d. Extreme Concentration to Dense Core Zones

Figure 3 shows, for each of the three Andean producer countries, the relative sizes of the geographic areas of 1) potential coca cultivation owing to the ecology of coca, 2) areas with any cultivation, 3) areas with licit cultivation, and 4) the central zones of the illicit cultivation regions. Central zones have cultivation densities of 4 hectares or more of coca per square kilometer – not dense in the absolute sense. Overall, the central zones constitute only 9 percent of the land area that has some cultivation, but they contain 59 percent of all cultivation. Although there are several dense central zones dispersed among the growing regions, this degree of concentration still aids counterdrug organizations to focus their operations.

e. Increasing Concentration Under Interdiction Pressure

Following the collapse of the Peruvian coca market and as fields were abandoned there, cultivation increased rapidly in Colombia. We analyzed the pattern of growth or decline of cultivation across regions based on their average cultivation densities in 1997.

---

10 Cuerpo de Asistencia para el Desarrollo Alternativo (CADA) provided a map of the full 10 x 100 kilometers of cultivation region on a scale of better than 1 centimeter = 1 kilometer for the year 1997. Although CADA also provided a detailed map of Aguaytia, we could not determine whether the many small rivers indicated on this map were dry or flowing during the harvest, hence the analysis of distance to the nearest river would be ambiguous. The "opportunity model" of travel frequency from human geography would predict an exponential distribution of farms from the nearest river if they all are constrained by access to those rivers (Ref. 4, pp. 537-43). The distance from coca farms to the nearest river in the Apurimac does form an exponential distribution verifying theoretical expectation.

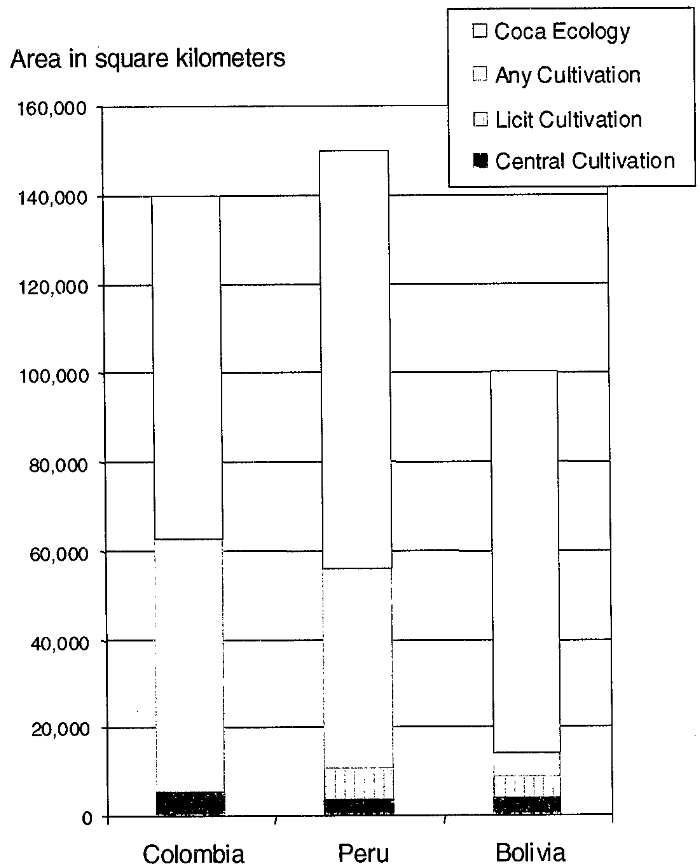


Figure 3. Concentration of Coca Cultivation for 1997

The annual Crime and Narcotics Center (CNC) satellite surveys of coca cultivation provide reliable data on the growth or decline of each region over the period from 1995 through 1998 (Ref. 5). We found that the outer limits of growing areas tend not to change very much during decline, while expansion often does spread to new adjacent land but generally remains compact. The best regression model explained the rate of growth or decline of the various cultivation regions as a power-law function of regional density and a factor representing Colombia's unique advantage.[11]

Colombia's growing regions enjoy a 70 percent per year rate of increase in cultivation over regions of comparable density in Peru or Bolivia. We believe this reflects the relative security situation for coca traffickers in these three countries since

---

11 The linear regression fit of a log-log model was quite good, with an R^2 of 0.96.

government forces can move freely within Peru and Bolivia but not in Colombia. Denser growing regions in general have an additional 16 percent growth rate (or reduced decline rate) per year advantage over regions of half their density and an 81 percent advantage over regions with one-tenth their density. The key conclusion is that pressure from interdiction operations have greatly *increased* the concentration of the illicit coca cultivation in all Andean source countries. Even if some new cultivation has developed in unsurveyed areas, it could not contribute significantly to this analysis because, to be large enough to have an impact, it would have been detected and surveyed. This increased concentration *of air interdiction areas* creates opportunities for decisive engagements that might abruptly block trafficker access to the bulk of today's coca crop.

f. Refuting the Expansion Assumption

The evidence from all Andean countries following the collapse of the Peruvian coca market refutes the expansion assumption. Within Peru, some dispersed regions of cultivation had expanded during a strong coca market while fungus problems were stressing the traditional core region, the Upper Huallaga Valley; during weak market conditions these dispersed regions were quick to collapse. Although Bolivia formerly supplied coca for the European market, its decline matches that of Peru's. The dispersion of Bolivia's cocaine laboratories to small-scale operations coincided with the loss of large trafficker organizations and of access to essential chemicals to produce a quality product. Since a low quality product would not sell in the European market, this undermined Bolivia's most lucrative market. The remaining large and efficient production regions are in Colombia and are increasingly concentrated – for agronomic, economic, and security reasons. Thus, production efficiency appears to demand concentration of cultivation. Efficiency, rapid turnaround, and process control most likely cause cocaine laboratories to concentrate as well. Together, these factors appear to explain why the evidence contradicts the expansion assumption.

2. Denying Air Transport Caused Coca Market Collapse

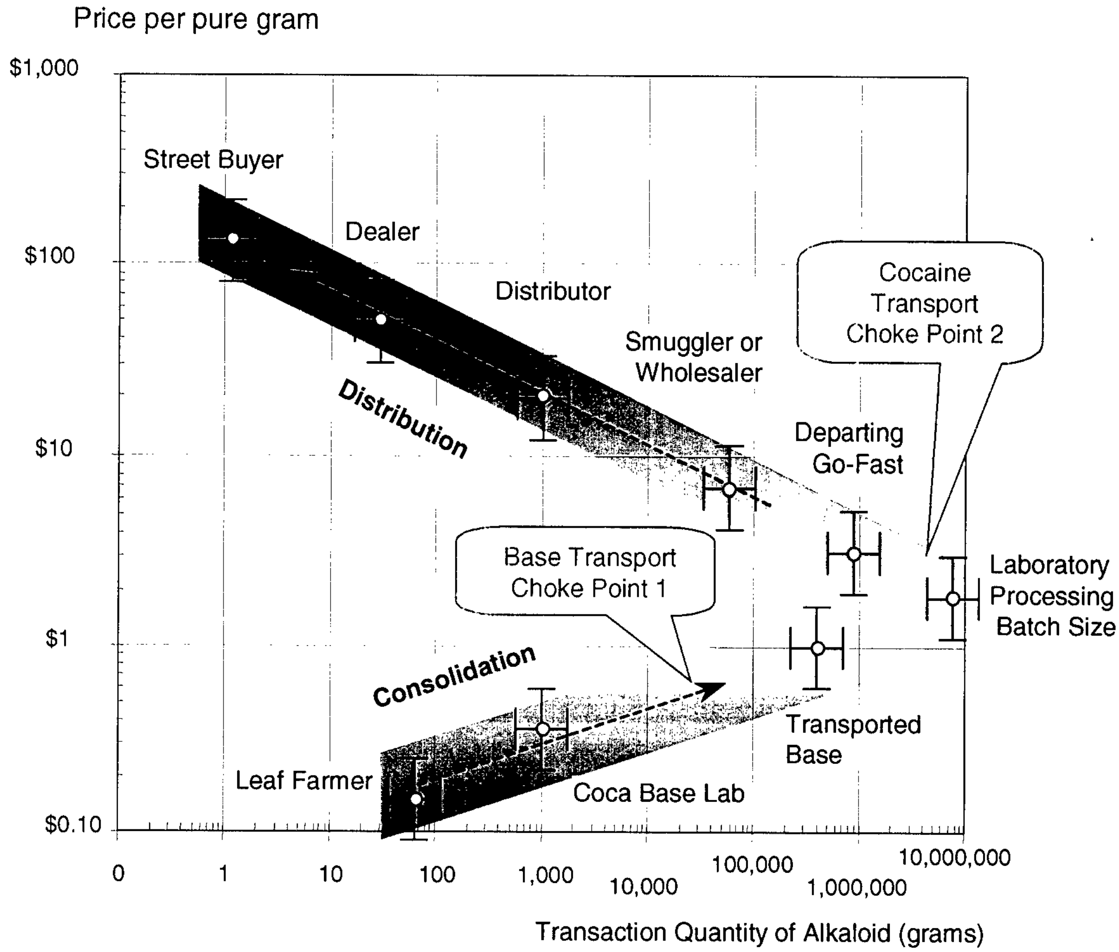
Traffickers depend upon air transport contractors to get coca base from the growing areas to cocaine laboratories and from laboratories to transshipment points. Any significant break in that chain causes a collapse in the isolated producer market and severe shortage in the remaining distribution market.

a. End-to-End Price-Quantity View of the Cocaine Business

A broader view of the entire cocaine business reveals that these source-zone air routes are true choke points in the essential chain of buying and selling that extends from farmgate to street consumer. We analyzed this chain of buying and selling steps by plotting the price per pure gram of cocaine alkaloid against the transaction quantities at each step, also measured in equivalent grams of pure cocaine. The results are shown in Figure 4. For each transaction, the factor of two uncertainty range (depicted by the vertical error bars) spans the typical dynamic price variation, which is addressed later in this summary and in Chapter V. Similarly, the factor of two range of variability in transaction quantity (depicted by the horizontal error bars) applies to amounts of transported base, laboratory batch sizes (major labs), go-fast loads, and transactions quantities, both wholesale and retail, in the U.S. Although there are many parallel and branching distribution chains from laboratory to street buyer that when averaged together form a continuum of quantities and prices within the U.S., each individual chain is typically characterized as shown: four approximately equally spaced transactions on a log-log plot.

The most striking feature of the cocaine business shown in Figure 4 is the uniform progression of price increases, first as quantities of alkaloid concentrate from farmgate to cocaine laboratory and then as they distribute from laboratory batches to street purchase quantities (Ref. 6; Ref. 7, pp. 748-57). The uniform progression from cocaine laboratory to U.S. consumer results from a constant markup relative to a given number of sales at each step. Typically, a trafficker in the cocaine distribution chain buys a quantity, Q, at unit price, p, and sells to each of 30 customers an amount, $Q/30$, at unit price 2.5 x p. For this, the trafficker receives $2.5 - 0.1 = 1.5$ times their investment no matter which quantity Q or unit price p they deal with along the distribution chain.[12]

[12] This structure is most clear for the lower levels of the distribution chain (Ref. 6; Ref. 8, pp. 1,364-1,371; Ref. 2, p. 294). The markup value changed very slowly between 1983 and 1998. The value of 2.5 is reasonable for the 1990's, while previous work gave a slightly larger value of 2.6 that included data from the 1980's (Ref. 6). Also, we plotted typical quantities for go-fast transit and cross Mexican border smuggling, which deviate slightly from the idealized x 30 breakdown. Nevertheless, the observed values fit the trend from the idealized model as shown in the plot.



Sources: all STRIDE in US, various for Colombia, 1998 UNDCP Peruvian leaf and base

Figure 4. Price-Quantity Relationship for Steps in the Cocaine Business

This uniform progression can be understood from two different perspectives – balancing risks and profits among the steps or equal return on investment. Balancing risks and profits means that traffickers come to understand that the profitability of steps above and below them are the same as their own. If an adjacent step were to become more profitable relative to its risks, over time traffickers above and below would encroach to equalize its markup profitability. The alternative explanation, equal return on investment, derives from traffickers expecting to get a standard price markup on their at-risk capital for any step in the chain. During the period from 1995 through early 1999, the idealized distribution chain marked up prices 2.5 times for each step, assuming

that traffickers break down a purchased load and resell to approximately 30 customers. These high markups reflect the high risks and large losses along the distribution chain. Since roughly half of the cocaine does not successfully make the trip from laboratory to street, this translates into an average 15 percent loss at every step in the transaction hierarchy shown in Figure 4.

This analysis of the end-to-end chain from farmgate to consumer implies two key points:

- Each level of the distribution chain operates as a separate business, not integrated with those above and below, but nevertheless dependent upon them.
- There are two important cocaine air transport choke points in this distribution chain – from base laboratory to cocaine laboratory and/or from cocaine laboratory to transshipment point. It is these choke points where the cocaine industry is most vulnerable to structural intervention.[13] If most of the transport at either of these choke points is blocked, coca before the block has no market and prices drop while coca products beyond the block are scarce; thus, their prices rise. However, a blockage of the majority of the transport would strangle the flow and the cocaine business – no matter what the prices and fees might be.

b. Major Interdiction Operation

According to the Bureau of Justice Statistics, "interdiction is the prevention of illegal drugs from entering the U.S. from foreign sources or transit countries by intercepting and seizing such contraband" (Ref. 9, p. 146). This definition is, unfortunately, misleading because it does not consider the large amount of drugs deterred from shipment. Although interdiction does involve intercepting and seizing contraband, its real purpose is to *deter* traffickers from continuing their illicit activities. Effective deterrence causes the bulk of cocaine not to be transported at all. If it is not transported, there are few seizures. Recognizing the deterrent aspect of interdiction operations is crucial to understanding why such operations can be practical, effective, and sustainable. At essence, the difference is the use of military-style interdiction operations (vice

---

[13] It was brought to our attention in a recent trip to Peru that the cash supporting these large transactions must also be transported to the buyers because the illicit trade relies on cash-only exchanges in Peru. Cash shipments, of course, are even more vulnerable to theft by rivals or other losses and present a collateral choke point.

seizures) to destroy the viability of key sectors of the cocaine industry as envisioned and executed under Presidential Decision Directive 14.

We define a "major interdiction operation" as one that engages a vulnerability of the cocaine business on a wide enough scale and in a short enough time that it has the potential to inflict significant structural damage and a serious shock to the overall cocaine business. Note that this definition does not explicitly refer to the general level of effort of the USG or its allies in counterdrug operations, but rather only to the impact on the cocaine business. It focuses on the potential specific actions designed to cause a catastrophic failure and collapse of a key sector of the cocaine industry such as transportation or laboratory processing. In terms of their focus, scale, and duration, several air interdiction operations in Peru from 1991 to 1996 satisfied this definition by causing significant damage to the illicit coca business.

c. Effectiveness of the Major Operations Against the Air Bridge from Peru to Colombia

Four air interdiction operations stand out in the collected research materials as significantly disrupting the Peruvian coca market:

- The Colombian crackdown began on 19 August 1989, and U.S. President Bush declared a "War on Drugs" on 5 September. By November 1989, the crackdown had turned into an obsessive chase for Pablo Escobar and Jose Rodriguez Gacha. In January 1990, the landing strip at the SLB for interdiction aircraft in the heart of the Peru's principal growing region, the Upper Huallaga Valley, became operational and interception flights from that base significantly reduced the number of trafficker flights into and out of the surrounding growing areas.
- Operation Support Justice III (SJ III) began September 1991 in Colombia (November in Peru) and ended on 29 April 1992.[14] This short operation was quite effective in reducing traffic, and coca prices fell in response. However, in the confusion, FAP pilots fired on a USG C-130 killing one airman. Soon afterward the USG ended the operation.
- Operation Support Justice IV (SJ IV) began November 1992 in Colombia (January 1993 in Peru) and ended on 1 May 1994. This operation resumed

[14] Support Justice I and II were short training exercises. Although SJ II produced noticeable success with an interdiction and 42 aircraft seized, producing a small dip in coca base prices, it lasted less than 2 months and cannot be called a "major" operation.

USG D&M support, but under tight restrictions on engagements to prevent another U.S. fatality. Although coca prices dropped significantly, traffic continued unabated, transporting essentially all available coca base. The operation ended when Colombia wanted to resume lethal engagements, and the USG withdrew support until there was a legal review and finding governing the U.S. conditions for resuming D&M support.

- <u>The resumption of U.S. D&M support</u> for a potentially lethal interdiction endgame began in January 1995 in Colombia, but effectively began for Peru in March 1995. This operation was an immediate success because illicit traffic plummeted for the next seven months and coca base prices dropped well below breakeven costs. There were substantial reinforcements to sustain the operations in September 1995, and operations continue today with only a brief stand-down in December 1995. Note that the USG initial support was dubbed operation "Green Clover" until April 1996 when a follow-on operation called "Operation Laser Strike" commenced.

One of the authors of this report spent 4 months in Peru as a U.S. Embassy staff intern researching the then recent collapse of the coca economy. He had access to all of the counterdrug and alternative development teams at the U.S. Embassy in Peru and spent significant time with original Peruvian sources. In addition to reviewing both unclassified and classified materials, he interviewed those analysts in depth. He was also able to interview Peruvian journalists, academics, and independent alternative development agency staff, and was given access to many of their archives. Although this process uncovered many collateral events that influenced the illicit coca business in Peru, only the air interdictions and eventual severing of the air bridge consistently explains the collapse of Peruvian coca prices and cultivation.

There were many collateral events during the period of this analysis. One example is "Fujishock," the floating of the Peruvian currency on 8 August 1990, which caused a rapid doubling of coca production costs and prices. Another example is the capture of Abimael Guzman, the leader of the Shining Path guerrillas, after which their influence plummeted, enhancing government control within the growing areas. Although these and other events may have been contributing factors, none of them can be credibly argued as the primary cause of significant damage to the coca market.

In subsequent trips to the U.S. Embassy in Peru and to the UNDCP office in Lima, this research team encountered universal agreement that the interdiction of the air-bridge caused the collapse of the coca market. In retrospect, we recognize that several

factors contributed to the success of the air interdictions against the air bridge traffic to Colombia as well as to the subsequent movement toward a reduction of lawlessness in Peru:

- The Peruvian Government strongly supported the counterdrug effort, placing it second only to fighting border wars with Ecuador or internal insurgency movements. However, President Fujimori demanded that there be alternative development aid as well as military assistance from the USG. It is likely that resentment towards the insurgents by the source-zone populations contributed to gaining the information necessary to capture their leader and diminish their influence, thereby increasing security in the countryside.
- DEA operations in conjunction with the Peruvian National Police (PNP) provided valuable information about how the illicit coca business functions, which informed the process of planning air interdictions and interpreting economic data.
- The "Fujimori Doctrine" of attacking the traffickers and not the coca farmers reduced general hostility toward the central government of Peru. For example, eradication became a much more voluntary program, generally conducted on government land or in conjunction with alternative development programs.
- United Nations and USAID alternative development programs were able to collect useful time series of illicit coca prices that formed a basis for evaluating economic impact of interdiction operations.
- Alternative development programs further improved police presence, security, and support for a population formerly threatened by violence from insurrection and traffickers. Farmers were willing to accept up to a 60 percent reduction of income to avoid the violence associated with illicit coca.[15]

3. Deterrence Enables a Few Interdictions to Block Most Traffic

With the threat of lethal consequences, interdicting only a small percentage of trafficker flights, as few as 3 percent of potential flights, was sufficient to deter more than 80 percent of the other trafficker pilots from flying. Because air traffic is

[15] This early finding from alternative development survey research was relayed to us during a 1999 trip to Peru.

susceptible to detection and monitoring, a small air force can achieve the necessary rate of interdiction to deter transport on routes from Peru to Colombia.

a. Psychology of Deterrence

The U.S. Customs Service sponsored a consulting research group within Rockwell International to interview confidentially 112 former drug smugglers incarcerated in Federal prisons (Ref. 10). These former smugglers were asked questions concerning the conditions under which they would be willing to continue various illicit activities. Although interview data are opinions of smugglers, such *opinions* are the ultimate basis for deterrence.

The interviews revealed that owners of drugs are willing to sustain high loss rates averaging as high as 30 percent, but the contract smugglers themselves are not willing to face capture or incarceration at anywhere near this rate. For example, most said they would be deterred by a 10 percent chance of being caught if the consequences were conviction and imprisonment. During these interviews, however, some smugglers admitted that modest risks actually attracted them to smuggling. Thus for a low level of risk of interdiction, smugglers essentially ignore the risks. These facts indicate there is a threshold of deterrence – an interdiction risk below which there is no deterrence and above which increasing numbers of smugglers are no longer willing to take the risks and quit. This deterrence threshold depends, of course, upon the severity of the consequences as well as the probability of interdiction.

As the interdiction risk increases, fewer smugglers are willing to continue. Although the interview questions on willingness to smuggle did not mention any increase in fee for taking more risk, we can infer from later questions on the willingness to take more risk for more pay that the respondents answered the first questions assuming higher fees for more risk.

b. Mathematics of the Willingness to Smuggle

These interview results were remarkably useful for determining the mathematical form of a function $W(P_I)$, which represents the fraction of the inmates willing to smuggle against a risk P_I of being interdicted. After evaluating several alternative formulations, we fit the interview responses as grouped data to the parameters of the best

functional form for $W(P_I)$.[16] We also assumed that a single exponent could represent all six sets of conditions explored by the interviewers to obtain the following: [17]

$$W(P_I) = \left(\frac{P_I}{P_{\min}} \right)^{-1.03 \pm 0.07} \qquad \text{for } P_I \geq P_{\min}$$
$$= 1.0 \qquad \text{for } P_I \leq P_{\min}$$

Here, the parameter, $P_{\min}$, represents the threshold probability of interdiction at which smugglers begin to be deterred. At probabilities of interdiction less than $P_{\min}$, smugglers ignore the risks and all are willing to smuggle. Of course, $P_{\min}$ depends on the consequences of interdiction, and more severe consequences lower the value of $P_{\min}$ at which some smugglers are deterred. Although the fitted exponent of -1.03 ± 0.07 in $W(P_I)$ is consistent with being –1.0, we preserve this small difference because is shows the uncertainty bounds on the exponent and reveals any sensitivity the model may have to deviations from –1.0.

Because the model is consistent with a simple reciprocal, that is, an exponent of –1.0, it may represent a more general law of human behavior than just avoiding the consequences of being caught smuggling. For example, data from the early days of automobile use in the United States show that, from 1900 to 1910, the fraction willing to drive increased in inverse proportion to decreasing fatality rate per hour of driving (Ref. 11). In 1900, for example, there was a 0.5 percent chance of a fatal accident in each
8-hour trip – automobile use was an "extreme sport." By 1910, nearly one percent of all Americans were driving and risks had dropped 50-fold. Thereafter, up to 1930, the percentage of Americans willing to drive increased more rapidly than the risks fell, and from the 1930's to the present, safety increased faster than usage. Thus, the 1900 to 1910 period suggests that the willingness of the most adventuresome fraction of a

---

16 Appendix A shows that neither alternative, a Pareto nor an exponential distribution, even qualitatively fit these data. Chapter IV shows that the Peruvian air interdiction operations fit our selected model very well and validate the existence of a threshold as in our inverse power law model.

17 We fit the best functional form to a single exponent of –1.0, but this does not provide an uncertainty estimate for the exponent. We also fit the functional form to six separate exponents, one for each case, but these produced large standard error estimates due to the large correlation between the exponent, α, and the interdiction threshold, $P_{\min}$. Within those large error ranges, the separately fit exponents were also consistent with –1.0.

population may adjust their level of participation in very risky activities in direct proportion to the degree of risk. This is mathematically the same function as that for willingness to smuggle.

A recent study of law enforcement for fisheries (Ref. 12), done for the U.S. Coast Guard, revealed that a similar deterrence model can be used to represent the observed violation rate as a function of Coast Guard enforcement activity levels. This corresponds to a reasonable analogy for the willingness to smuggle function described in this paper. Interestingly, this study found that for the two districts with the largest data samples, Coast Guard Districts 1 (Boston) and 7 (Miami), the fitted exponents for the "deterrence" model were indistinguishable from –1.0 (District 1 had an exponent of –0.96, with a 80 percent level of confidence interval of ±0.15, and District 7 had –0.95, with an interval of ±0.16).

Figure 5 shows the willingness function, $W(P_I)$, overlaid with smuggler interview data from four of the six cases with different interdiction consequences. Here, the smuggler data are presented as cumulative fractions of inmates who were willing to smuggle at risks less than or equal to the indicated probability of interdiction.

In the interviews, smugglers were asked whether they would personally (designated *self*) continue against various interdiction odds. They were also asked to imagine a former *associate* and to answer the questions as if they were that person. For all cases, the inmates imagined their former associates to be less deterred than themselves. Some inmates volunteered that had they not underestimated the likelihood and consequences of being caught, they probably would not have continued smuggling. It is likely that they answered for their "associates" as if they were still smuggling.

The thresholds for various values of $P_{\min}$ are clearly visible in Figure 5 along the upper border. These represent the break from 100 percent willingness to smuggle to the onset of deterrence. There is also a residual fraction of the smugglers who are willing to smuggle *knowing* they would be interdicted. Some of the inmates even volunteered this during their interviews; they said they could earn more for their families by one smuggling attempt than they could earn in legitimate employment for the entire period they would spend in jail. Because our interest here is to represent classes of smuggler behavior, we show $P_{\min}$ values and boundaries defining those classes in Figure 5.

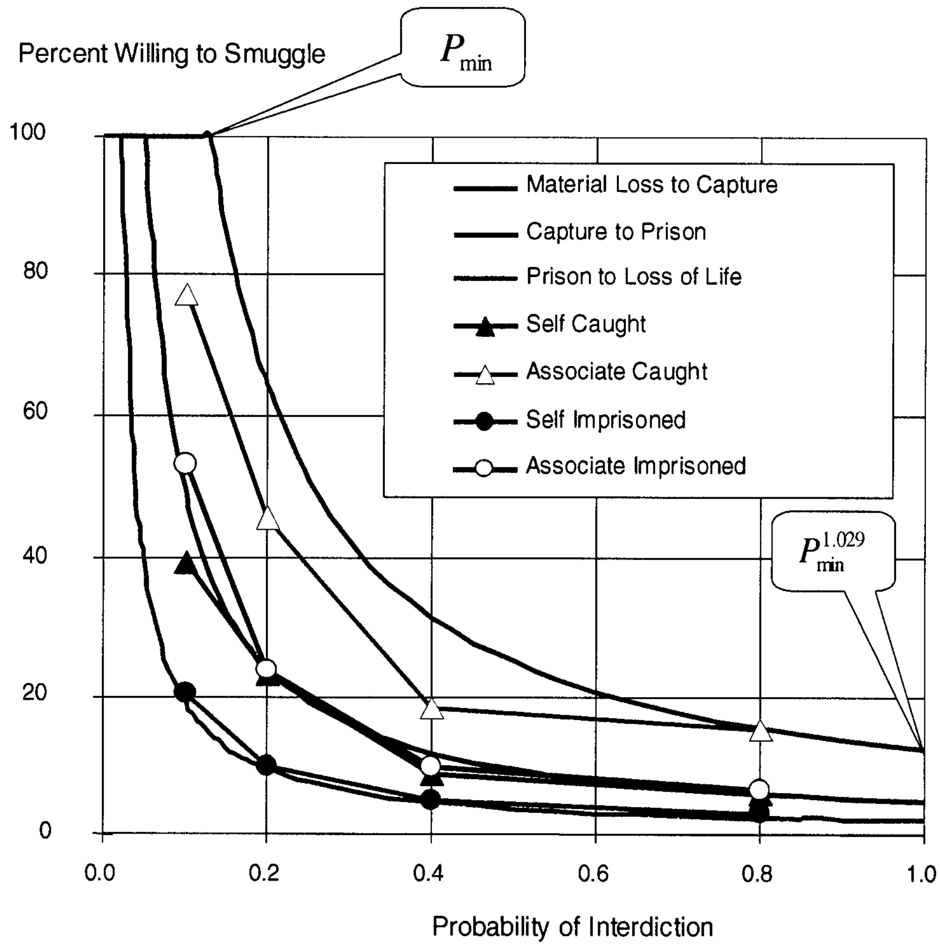


Figure 5. Willingness to Smuggle Function with Representative Data

We have fit exact P_{min} values to each of the six distinct interview cases; however, classes of cases are more useful for operational analysis and planning. For example, all three cases for smuggler answering as "self" fall in the range from P_{min} of 2 to 5 percent. The three cases for "associate" fall in the range from 5 and 8 percent. For owners losing loads because smugglers abandon them to escape, the average is at 30 percent, which we have taken to be a threshold. We noted that all these thresholds, with a slight adjustment for "associate," appear to form a geometric progression beginning at 2 percent and

increasing with a scale factor of 2.5. Such a geometric progression is consistent with earliest representations of human perception:[18]

- 2 percent
- 2 x 2.5 = 5 percent
- 5 x 2.5 = 12.5 percent
- 12.5 x 2.5 = 31.25 percent.

Therefore, we chose boundaries at 2, 5, 13, and 30 percent as the operational zones that span distinct classes of cases for a complete willingness function.[19]

We found several functions and examples that are closely related to our willingness function in the literature on the psychology of risk perception. The most widely accepted model of risk perception by individuals is the conjoint expected risk (CER) model, which uses a power-law to mathematically represent the risk perceptions (Ref. 13). Several alternative psychological models have been proposed and rejected as not fitting the experimental data. These include ones based on comparing expected gains with expected losses, ones based on comparing expected gains with the variation due to uncertainty, and ones using exponential rather than power-law functions (Ref. 13; Ref. 14).

The inmate interviews also explored the possibility that increased wage offers could offset the increased interdiction risk. Our analysis showed that even 10 times more wages could not sustain the same level of trafficking as risks increased; for example, at three times the risk, only one-third could be induced to continue, and at four times the risk, less than one-quarter would continue smuggling. Moreover, the wage rates to induce these smugglers to continue increased much more rapidly than the risks. This result is consistent with the behavior of gamblers, who discount money rewards for taking risks at about the square root of its face value (Ref. 15).

---

[18] Weber's law says that the just noticeable difference (JND) grows larger in direct proportion to the size of the stimulus (Ref. 15, p. 9). Although perception of stimulation increases as a power law, successive increments of JND increase in proportion to the logarithm of intensity. Here, it is successive classes of perceived risk in proportion to the logarithm of interdiction probability.

[19] The thresholds at 13 and 30 percent are the subject of ongoing research. However, these thresholds do not affect the operational utility of the willingness function for operational planning because operations depend on the lower thresholds that are precisely known from comparison with real operations.

In order to reconcile the inmate responses underlying the willingness function with those exploring the ability of higher wages to offset risks, we found that the willingness function implicitly includes an assumption of higher wages to continue to smuggle against higher risks.

c. Mathematics of Deterrence

Smuggling success depends upon both the willingness to attempt to smuggle and, if attempted, the ability to avoid interdiction. Conceptually, the probability of smugglers being thwarted, P_t, i.e., being interdicted or deterred, can be expressed mathematically as follows:

$$P_t = 1-(1-P_I)\cdot W(P_I)\,.$$

The right side of this equation is easily interpreted if read from right to left: of the fraction, $W(P_I)$, willing to fly coca to Colombia, some of these, $1-P_I$, successfully complete their flights; therefore, 1.0 minus this successful fraction is the *thwarted* fraction.

Knowing the function representing the willingness to smuggle enables us to give a specific form to the deterrence model:

$$\begin{aligned} P_t &= 1-(1-P_I)\cdot\left(\frac{P_I}{P_{\min}}\right)^{-1.03\pm0.07} && \text{for } P_I \geq P_{\min} \\ &= 1-(1-P_I) && \text{for } P_I \leq P_{\min} \end{aligned}$$

Therefore, $P_{\min}$ defines a *non-linear* break point transition between no deterrence, $P_I \leq P_{\min}$, and onset of deterrence, $P_I \geq P_{\min}$. Also, the certainty of interdiction at $P_I = 1.0$ collapses to zero the residual fraction, $P_{\min}^{1.03}$, willing to smuggle knowing they will be interdicted.

Figure 6 shows this full deterrence model along with the representative interview data and zone boundaries from Figure 5. Here, we have added a new zone corresponding to simple loss of drugs with a threshold at 30 percent and following the model form with exponent −1.03. Figure 6 shows that for any given interdiction probability above a deterrence threshold, the fraction of thwarted smugglers divides into two components: those simply interdicted and those others deterred from smuggling. Because of the penalty conditions for coca smuggling, the thresholds are low, the increase in deterrence

above threshold is rapid, and modest levels of interdiction can thwart 80 percent of the smugglers.

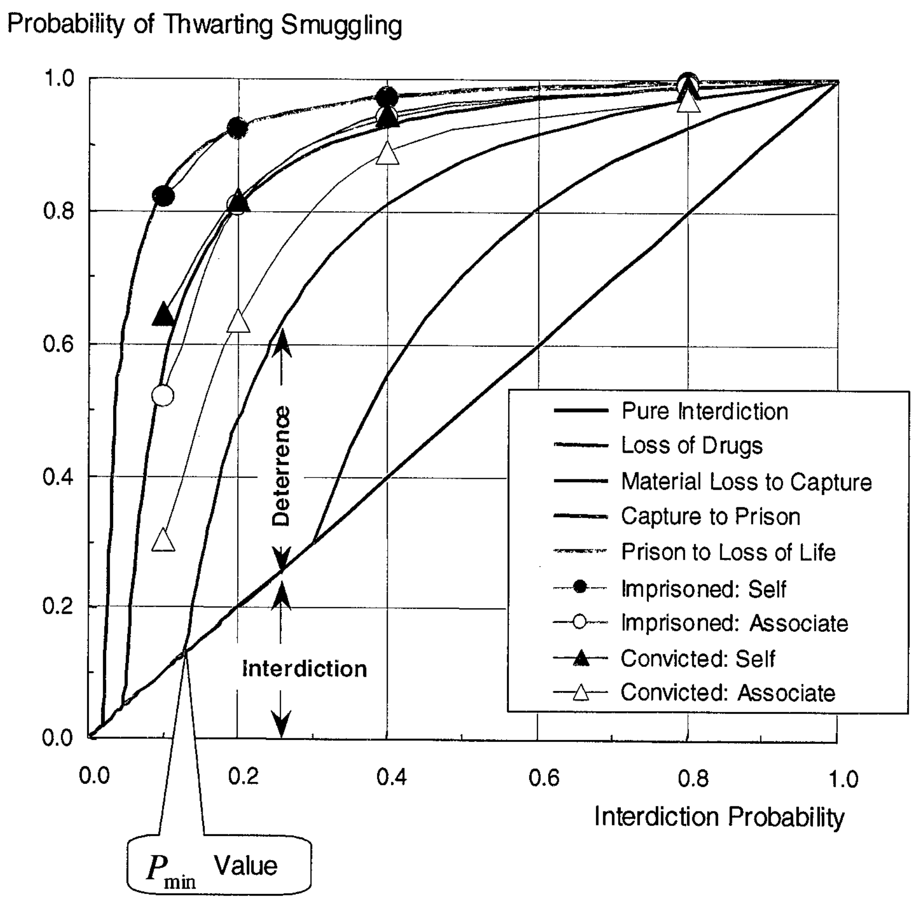


Figure 6. Deterrence Model Showing Representative Trafficker Interview Responses

Each of the deterrence curves in Figure 6 represents the predicted degree of thwarted traffic that is, interdicted or deterred, as the interdiction rate increases. The threshold of interdiction is the point along the pure interdiction line at which a deterrence curve breaks away from the straight line. Each deterrence curve is defined by threshold value of interdiction rate, P_{min}. The deterrence curves shown in Figure 6 divide five zones, which are defined by threshold values of P_{min} = 0.02, 0.05, 0.13, and 0.30, respectively. Each of these zones represent different consequences of interdiction for traffickers.

- Lethal Force ($P_{\min} \leq 0.02$): With the threat of lethal force, traffickers begin to quit challenging the interdictors when $P_{\min}$ reaches about 2 percent. Much below this threshold, however, traffickers are willing to accept the risks as a cost of doing business.[20]
- Personal Imprisonment ($0.02 \leq P_{\min} \leq 0.05$): If experienced traffickers anticipate a severe sentence whenever they are captured, they will begin to be significantly deterred in this range of interdiction probabilities.
- Capture and Imprisonment of an Associate ($0.05 \leq P_{\min} \leq 0.13$): Those who have not experienced prison life may be more difficult to deter and require thresholds in the range from 5 to 13 percent.
- Loss of Boat or Aircraft ($0.13 \leq P_{\min} \leq 0.30$): This zone of interdiction threat includes loss of the drugs as well.
- Loss of Drugs ($0.30 \leq P_{\min} \leq 1.00$): Interviews with inmates and observed avoidance behavior when threatened with interdiction indicate another zone for loss of drugs.

d. Quantitative Analysis of Real Interdiction Operations

To estimate P_I and P_t from operational data from Peru requires several time series from the air interdiction operations. Fortunately, these data were collected by the Narcotics Affairs Section (NAS) and the Tactical Analysis Team (TAT) of the U.S. Embassy in Peru. The verification of the traffickers' responses against real-world interdiction operations makes this model very valuable in estimating the forces necessary to interdict *and* deter drug trafficking in future interdiction operations.

Two data sets provide a measure of the probability of interdiction, P_I: verified interdictions of flights over the air bridge divided by detected and identified trafficker flights over the air bridge forms a ratio that estimates P_I. Two other data sets provide a measure of the probability of interdicting or deterring traffickers, P_t: the metric tons of coca base that were detected being transported over the air bridge divided by the metric tons of coca base potentially produced in Peru for transport over the air bridge. This

[20] A more detailed examination suggests that traffickers ignore lethal interdiction rates of up to about 0.5 percent. The actual threshold for deterrence with lethal consequences is probably about 1.0 percent, but no higher than 3.5 percent. See Figure IV-11.

latter ratio estimates the *successful* trafficker transport, P_s, from which it is easy to compute $P_t = 1 - P_s$.

In addition, we had to make adjustments to the raw data for more than 20 sources of uncertainty to obtain a best estimate of the above ratios and their uncertainty estimates. These sources of uncertainty include statistical fluctuations, undetected flights, purity of the base being flown to Colombia relative to that of the refined cocaine, and estimating the fraction of potential production consumed internally or transported by other means. The statistical fluctuations on the small number of air interdictions are one of the largest sources of uncertainty. This, combined with systematic uncertainties generated by actual pulses of trafficker flights, led us to group the monthly data into operational periods of 6- to 12-month's duration as shown in Table 1. Note that these periods break at operationally meaningful events with an expectation of consistent operational conditions throughout the period. For example, the attacks on Colombian cocaine laboratories in December 1996 through January 1997 caused demand for new coca base from Peru to drop suddenly, and recovery took approximately 7 months.

Figure 7 shows the deterrence model overlaid with the first ten of the above operational periods.[21] The open circles and black line in Figure 7 show the complex sequence of interdiction conditions in Peru for each of the ten operational periods.[22] Open circles characterize each operational period in terms of their interdiction levels and corresponding levels of interdiction and deterrence. The heavy black lines simply connect these circles indicating the sequence of operational periods.

---

21 The eleventh operational period, "Sustainment 2," has coca cultivation data but not interdiction data; it begins 1 month after the end of the tenth operational period.

22 In Peru, there was a nearly constant number of interdictions per month for all operational periods with D&M support. The force-down/shoot-down policy lowered the P_{min} threshold due to the lethal threat, which began to deter traffickers. Since the exponent is almost exactly -1.0, it turns out that a constant number of interdictions per month, which increases the interdiction rate as the traffic drops, is just sufficient to follow the deterrence curve and cause a near total collapse.

Table 1. Operational Periods for the Analysis of Deterrence

Operational Period	Beginning Date	Duration (months)	Comments on the Initiation of the Operational Period
Early	Mar-91	8	Air-tons data set begins here.
SJ III	Nov-91	6	SJ III ends soon after FAP shoots US plane.
Post-SJ III	May-92	8	This period is a lull between operations.
SJ IV Phase 1	Jan-93	9	Operations begin in Peru.
SJ IV Phase 2	Oct-93	7	Mid-point break is at dip in trafficker flights.
Post-SJ IV	May-94	10	USG suspends all military support to Peru.*
Early FD/SD	Mar-95	9	Peru gets renewed USG support.
Transition	Dec-95	12	Temporary stand-down of USG support.
CO Labs	Dec-96	7	Major Colombian lab complex attacked.
Sustainment 1	July-97	7	Effect of lab attacks wane.
Sustainment 2	Feb-98	11	End of interdiction data set for analysis.

* The Colombian Government was determined to engage trafficker flights with lethal force, but the USG must determine whether we can support this within the confines of international law.

The red line and filled circles in Figure 7 characterize the same ten operational periods but now as ratios derived from the raw data. Differences between the red and black sequences indicate the effect of all the adjustments due to sources of uncertainty. Note that most operational periods for both sequences follow the general shape of the deterrence model profile. Finally, the error bars about each open circle indicate our upper estimates of the standard errors due to the more than 20 sources of uncertainty. For all but 2 of 20 error bars, the raw data ratios fall within one standard error of the adjusted data values.[23]

The various operations in Peru follow the deterrence model and represent the traffickers' responses to extreme, that is, lethal, risk from air interdictions. Operation SJ III had some lethal interdictions and a significant degree of deterrence; however, it was not sustained after the FAP fired upon a USG C-130 aircraft killing one airman. The next operation, SJ IV, had tight constraints on lethal endgames and did not deter

---

[23] In some cases these standard errors were calculated without regard for logical constraints such as probabilities having to be between 0.0 and 1.0.

traffickers although the interdiction rates exceeded what would have been sufficient with lethal end games.

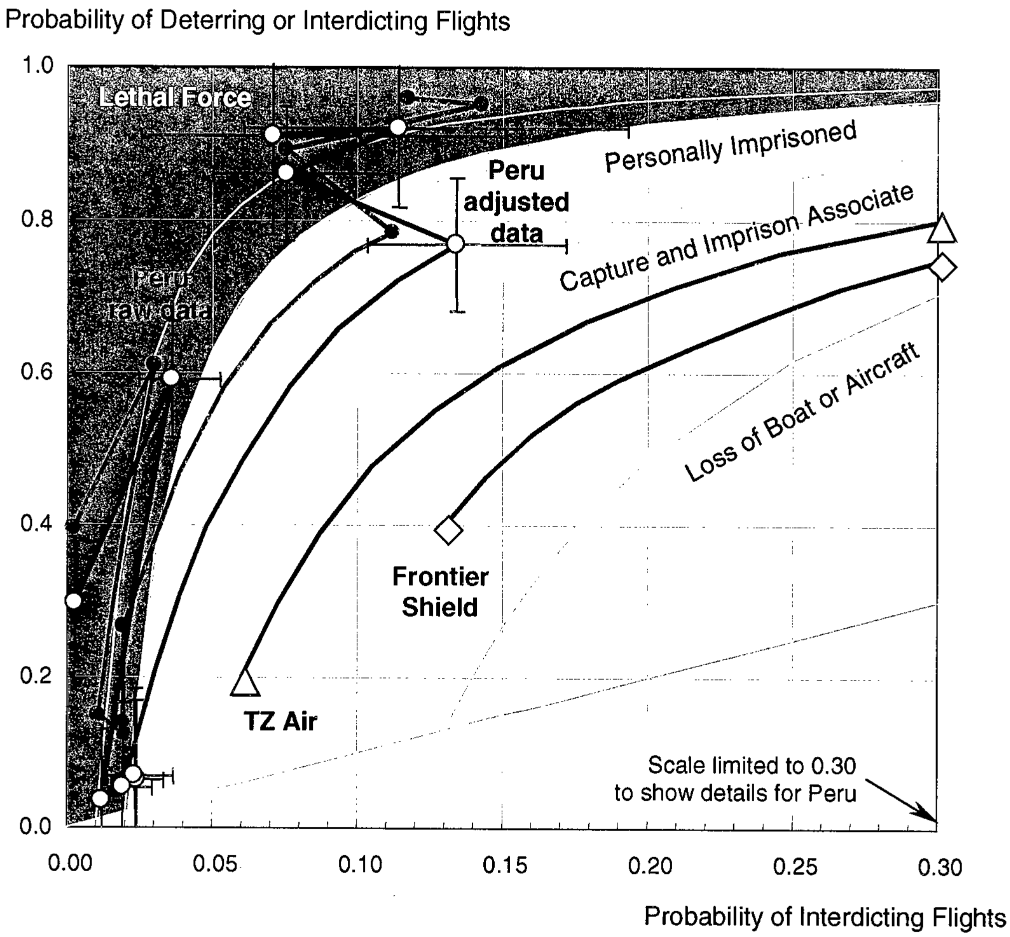


Figure 7. Deterrence Model Showing Peruvian Counter-Air Operational Periods

The "capture and imprison associate" zone characterizes two major transit-zone operations: the counter-air operations over the Caribbean and Frontier Shield against go-fast boats and planes in the eastern Caribbean. Although these operations consisted mostly of loss of aircraft or boats and the drugs, there were interdictions at both the points of embarkation and debarkation including arrests and imprisonment, which render the consequences comparable to imprisonment of associates (Ref. 16). Note that these operations also follow the pattern of the deterrence model.

In the following discussion, we more often refer to the probability of interdiction as the *interdiction rate*, which may be familiar to those in the military as the *attrition rate*. Pure interdiction is represented by the straight line beginning at the lower left of Figure 7 and gradually increasing upward to the right. If Figure 7 were not cut short at an interdiction rate of 30 percent in order to show the Peru operations in more detail, this interdiction line would eventually reach 100 percent chance of interdicting traffickers.

The principal lesson from Figure 7 is that interdicting a small fraction of trafficker flights can deter most of the other would-be smugglers. After the initial transition force-down/shoot-down (FD/SD) period with an interdiction rate of just over 13 percent, 7 to 12 percent interdiction rates continued to deter another 80 percent from smuggling. A more detailed examination shows that a 7 to 12 percent interdiction rate after the enforcement of the FD/SD policy represents only slightly fewer interdictions *per month* because there is so much less traffic than before the FD/SD policy. This illustrates the remarkable operational leverage provided by deterrence.

Military planners routinely use a 3 percent *attrition rate* as a heuristic rule to determine whether an air operation can be sustained or not. One can understand this by considering a military campaign with only 20 missions against a 3 percent loss rate because this translates into a net survival rate of only 54 percent. In Peru, with a force-down, shoot-down rule of engagement, an interdiction rate of 3 percent of the air traffic necessary to carry all coca base to Colombia caused the air bridge to collapse. Once the air traffic collapsed in Peru, the potential smuggler pilots faced an interdiction rate of 7 to 13 percent. These are daunting odds because only eight flights against an interdiction rate of 9 percent implies less than a 50 percent chance of survival.

Figure 8 shows the sharp increase of interdiction rate following the collapse of the air bridge from the "Early FD/SD" period onward. Although SJ III period involved some unsanctioned lethal interdiction and achieved some deterrence, it was short-lived. Figure 8 also shows the large standard errors due to the small counts of interdictions during each operational period. Nevertheless, these standard error ranges include the raw estimates of interdiction rate. Overall, however, Figure 8 shows the relatively low rate of interdiction necessary to deter another 80 percent of the potential trafficker flights after the implementation of the force-down, shoot-down policy.

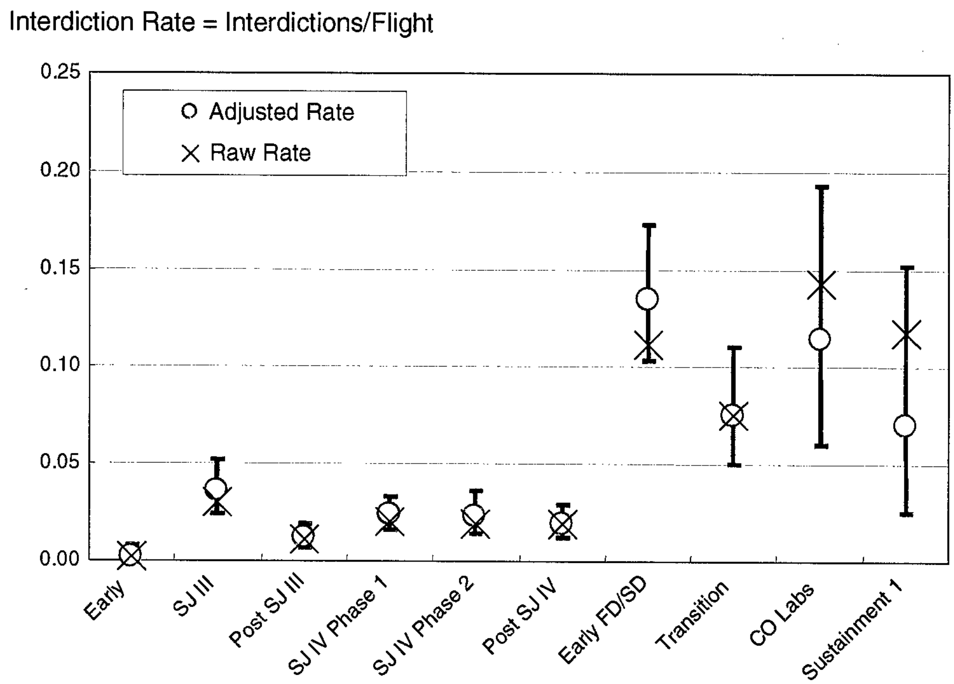


Figure 8. Adjusted and Raw Interdiction Rates with Statistical Uncertainties by Operational Period

e. Deterrence Thresholds and Operational Lessons

By determining which deterrence curve each operational period fell upon, we transformed the operational picture into the psychological framework perceived by the air traffickers. From this, we were able to learn several operational lessons related to the deterrence thresholds.

Given the consequences of being interdicted, the traffickers' psychology is dictated by whether the operational conditions are to the left or the right of their threshold deterrence curves in Figure 7. To the left of the deterrence curve, traffickers are below a threshold and ignore interdiction, while to the right, they are strongly deterred. For example, most of the open black circles in Figure 7 that represent lethal interdiction periods fall close to the deterrence model profile indicated as a contour of light gray within the red "lethal force" zone. The exceptions are the first and last operational periods and the "Early FD/SD" period, all three of which contain operational lessons:

- The "Early FD/SD" period occurred before the interdiction methods were refined. This illustrates an important point: unlike economic models of incremental or gradual change in which the efficacy of a policy should be revealed even by small incremental implementations, deterrence effects require reaching and exceedingly non-linear thresholds in order to see a significant impact of the policy.

- The "Early FD/SD" period includes a "pulse" of interdictions and the traffickers' gradual adaptation to the new, more intimidating conditions. Because of this pulse in the Peruvian operations, we cannot be certain whether the transition from ignoring the interdiction risk to near complete deterrence requires the "interdiction pulse." Frontier Shield also began with a pulse phase. However, the transit-zone air operation ramped up more gradually, and is our only case of a gradual onset of deterrence.

- The last period, "Sustainment 1," has very few flights and only two interdictions, as revealed by large horizontal error bars, but it is also well to the left of the gray curve for lethal interdiction. Once interdictors establish and sustain the credibility of their threat, deterrence seems to persist at even lower interdiction rates than the threshold might suggest. Because traffickers realize that interdiction forces are capable of intensifying their effort once again, there is little incentive for traffickers to attempt to rebuild a large network of flights only to see their investment in airfields, bribes, and accumulated drugs become worthless in the face of renewed government interdiction pressure.

We gained additional operational insights by computing an *interdiction fraction.* It is based on the ratio of interdictions in a time period divided by the total *potential* trafficker flights that might have flown if there were no deterrence.

- In Peru, the FAP maintained a constant interdiction fraction larger than P_{min} as trafficker flights collapsed, which was sufficient to sustain the collapse to very small levels of trafficking. Operationally this happened because the number of interdictions per unit time was sufficient even though the overall intelligence and interception process was capacity limited. Mathematically this happened because the declining traffic increased the effective interdiction rate enough to cause willingness to continue to decline.

- If the ability to detect and interdict traffickers had depended on the actual number of trafficker flights, then the interdiction rate itself would have been constant and the traffic would have declined only to the corresponding point on the deterrence curve – collapse would not have been complete.

Operationally this could happen if intelligence efficiency depended on the *number of flights* to detect.

By computing a P_{min} corresponding to the deterrence curve through each operational period, we obtained a best-fit P_{min} for all the lethal periods. After subtracting the first month of the "Early FD/SD" period as a pulse operation, the best-fit P_{min} was 1.2 ±0.5 percent. Note that the actual interdiction rates that deterred more than 90 percent of the flights during the "Transition," "CO Labs," and "Sustainment 1" periods were actually 7.5, 11.0, and 7.0 percent, respectively, but the inferred deterrence P_{min} thresholds ranged only from 1 to 2 percent.

For operational planning, the interdiction rate necessary to induce collapse for a lethal interdiction consequence should be much greater than this best-fit threshold of 1.2 percent. It should cover at least the uncertainty ranges of our analysis, that is, out to 3.0 percent. An early pulse of interdictions would assist in changing trafficker risk perceptions. After the pulse, an interdiction *fraction* of 2.0 to 2.5 percent should be able to deter another 70 or 80 percent of would-be traffickers.

As we mentioned before, this rate is consistent with the accumulated military experience of air combat operations in most wars of this century. It requires attrition rates of this level to defeat enemy air forces by forcing collapse of their capability to sustain operations. But note that the structural collapse of the Peru-to-Colombia air bridge is inconsistent with the purely law enforcement seizure and eradication strategy that has been economically modeled by others as a "tax" because such a limited law enforcement approach implicitly assumed away the possibility of structural intervention.

f. Refuting the Taxation Assumption

Because early policy thinking implicitly assumed that all interdictions in the source zone consisted entirely of seizures of coca products or illicit chemicals, or the eradication of coca plants, it also concluded that all source-zone interdiction merely "taxed" the traffickers with additional overhead. However, we see that modest levels of interdiction are capable of deterring nearly all air transport of coca base. This deterrence choked off the flow to Colombia in a strongly non-linear manner that isolated the Peruvian market and shrank Peruvian coca production. Attempts to represent the actual effects of interdiction with economic taxation models have not yielded useful results. The key parameters used in such models such as seizure rate fail to describe the actual

changes in the industry. For example, seizures remain constant or decline as smuggling flights decline yet, without smuggler flights, the coca business continues to be strangled. This shows that interdiction can damage the very structure of the illicit coca market rather than merely taxing its operation.

4. Indicators of Damage to Coca Markets Can Measure Operational Effectiveness

Too often those engaged in counterdrug activities come at the subject from a fixed perspective. The Peruvian experience highlights this with policy organizations accepting the common economic assumptions, with military planners focusing on operational data such as trafficker flights and interdictions, with law enforcement focusing on seizures and arrests, and the source-zone governments preoccupied with revolutionaries and U.S. market demand for cocaine. Our analyses focused on military operations that could cause structural collapse but, rather than relying upon strictly military or law enforcement measures such as seizures, flights events, or interdictions, we developed performance measures using indirect indicators of damage to the cocaine business such as commodity price changes.

a. The Interdictor's Dilemma

If an interdiction operation successfully deters trafficking, detected illegal activity declines. This response by the traffickers has been observed repeatedly as they attempt to adjust to the interdiction pressure. But does this mean that the illicit coca business is being damaged or simply that it continues in an as-yet undetected manner? Alternatively, if the trafficker activity continues at former levels, has the interdiction operation, nevertheless, caused disproportionate burdens for the illicit coca business? These questions define the interdictor's dilemma.

To know that the decline in trafficker flights is truly damaging the coca base market enough to warrant sustaining an operation while few traffickers continue to fly, interdictors must monitor the coca market indicators. In Peru, interdiction forces monitored the price of the primary commodity traded with Colombia – coca base. Other lagged economic indicators verified the severity of the damage; these indicators included information about coca field abandonment, other coca commodity prices, and depressed the economies in coca regions.

b. Coca Base Prices Resolve the Interdictor's Dilemma in Peru

Three principal alternative development and monitoring organizations collected base price data monthly in the 1990s: the UNDCP, the USAID/Peru Management Information System (MIS), and the Government of Peru's Proyecto Especial Upper Huallaga (PEAH). By the mid-1990's, the USAID/MIS had come to rely entirely on PEAH data.

The UNDCP data are collected from a wider variety of areas and are somewhat more sensitive than the PEAH data, which come exclusively from the most stable illicit growing region, the Upper Huallaga Valley. During the post-SJ IV period, the USG suspended all support to Peru including funding for PEAH data collection. Personnel at the U.S. Embassy in Peru estimate that PEAH values during this period from mid-1994 to early 1995 most likely were diluted by many resubmissions of previous data. Thus, we rely mostly on the UNDCP data for assessing operational effectiveness and on PEAH to assess coca production costs since the Upper Huallaga is the most stable market.

Figure 9 shows two time series for coca base prices in Peru overlaid with time series for trafficker flights, verified interdictions, major interdiction operations, and the production costs for coca base. By combining these data series on one plot, the reader can see the abrupt changes in coca price in response to the initiation of major interdiction operations. It also shows that the operational indicators of flights and interdictions do not always reveal this damage to the coca business. For example, during SJ IV without the threat of lethal interdiction, flights continued unabated, but the risks still caused coca prices to drop to the cost of production. Also, interdictions themselves remain nearly constant during each of the operations, but flights and prices collapsed after enforcement of the FD/SD policy. Note that the high attrition interdiction rates following the FD/SD policy as shown in Figure 8 coincide with the price drops in Peru shown in Figure 9. Even the attacks on major Colombian cocaine lab complexes correlate with a decline in the price of base in Peru, indicating a drop in demand.

c. Production Costs as Measure of Price Consequences

Based on several detailed accounts of the inputs of labor and chemicals to coca base production and the pricing of those inputs from the licit market, we were able to estimate the minimum plausible costs of production (Ref. 17; Ref. 18; Ref. 19).

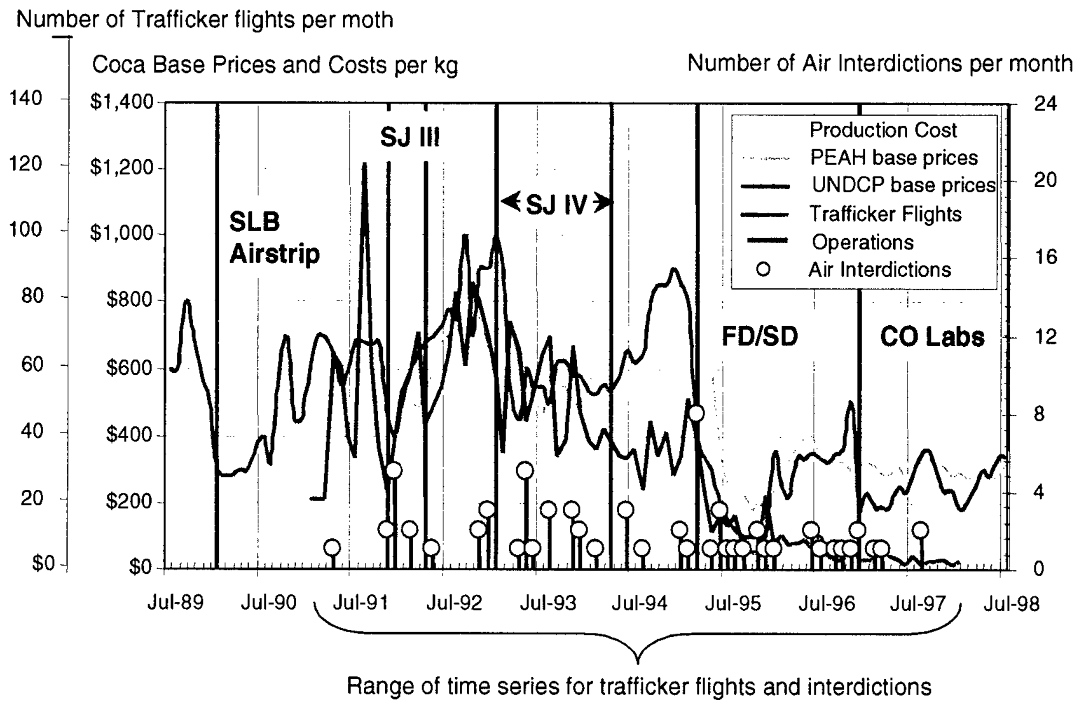


Figure 9. Coca Base Price Series for Peru Overlaid by Production Costs, Trafficker Flights, Air Interdictions, and Major Interdiction Operations

Comparing these estimates with the PEAH prices and concurrent cultivation expansion, maintenance, or decline, we obtained the following estimates of coca base production profitability:

- At over $1,100 per kilogram, farmers will recover the cost of new cultivation in a single year following the 2-year maturation process of newly planted coca. Therefore, extensive new cultivation can be expected if there are prospects for the market to remain high for 3 years.
- At $800 per kilogram and above, farmers will recover costs of new cultivation in 2 years but, again, the 2-year maturation process means they must believe prices will remain high for 4 years.
- At around $550 per kilogram, farmers will make a decent wage sustaining existing crops by replacing dead plants and tending healthy ones.
- At around $320 per kilogram, most farmers will stay in business but without investing in crop maintenance for the long term. This is at the brink of abandonment.

- At around $250 per kilogram, most farmers will abandon their fields unless there is good reason to believe that prices will recover within less than about a year.

These values are reported in current U.S. dollars per kilogram, thereby avoiding problems with the highly variable exchange rates and inflation in Peru. Those who wish to apply these thresholds might have to make adjustments for subsequent inflation.

The pilot's fee for air transport from Peru to Colombia was reported to cost less than $20,000 for 500 kg of base if unopposed. With non-lethal threats such as during SJ IV, fees rose to the $60,000 level, but with lethal post-FD/SD conditions, they rose to $200,000 or more. These huge fees demanded by smugglers, in addition to other security fees and bribes, were mostly born by the farmers with lower prices for their base and somewhat by the traffickers. Data are sparse for recent periods, but it is clear that bribes added to pilot wages raise transport costs to a high level – comparable to that of the coca base being shipped.

d. Overview of Operational Impact on Coca Business Indicators

Knowing this price structure enables interdictors to see that SJ III damaged the coca market for a short period before Peruvian fighters inadvertently fired upon a U.S. C-130 aircraft killing one crew member. This incident led to tight restrictions on lethal engagement throughout SJ IV. Support Justice IV did depress coca base prices due to the increased cost of transport, but this acted more as a tax than a serious impediment to the business. Following the enforcement of the FD/SD policy, however, prices plummeted, fields were abandoned, and 4 years of subsequent decline shrank Peru's cultivation by 66 percent. As Figure 9 shows, the price series fell immediately and continued at depressed levels causing continued business shrinkage. Only recently, not shown in Figure 9, have prices recovered, but there are only scattered reports of new planting.

5. Major Source-Zone Interdiction Operations Stress Cocaine Markets All the Way to U.S. Streets

Our previous discussion of the price-quantity relationship for the cocaine business from farmgate to U.S. streets explained that the cocaine market consists of many levels of quite independent traffickers and smuggling contractors. Because each

level passes the cost of avoiding risks on to the next level and each level receives comparable markups for comparable risks, prices *multiply* as coca products pass through successive levels. We will now see that this market structure also operates dynamically. That is, source-zone price increases ripple through these levels roughly in proportion to the original increase; this is a *multiplicative dynamic* market structure. The price series measured by our street price index often returns to but does not fall below $55 per pure gram, which we conjecture is the minimum cost of covering the risks for all levels of traffickers. By contrast, the street purity and casual use rates for cocaine fell without recovering after some major source-zone interdiction operations.

Repeatedly observed price rises and purity drops for cocaine sold on U.S. streets following shortly after major source-zone operations resolve the interdictor's dilemma where it counts most.[24] It also contradicts the taxation assumption, which claims that an 18¢ increase of coca base price per pure gram would be insignificant relative to the $55 street price. However, the evidence shows that these interdiction-induced street price increases are more likely to be $18 rather than 18¢.

a. Dynamics of Multiplicative Market

Previous work at IDA analyzed data from the DEA's System to Retrieve Information from Drug Evidence (STRIDE) (Ref. 6; Ref. 20). This database summarizes price and purity for tens of thousands of individual cocaine purchases made by undercover agents since 1981. Because purity varies from a complete swindle (zero purity) on up to more than 90 percent pure cocaine, IDA normalized the price to equivalent pure grams by dividing price by purity.[25] To avoid the statistical fluctuations that rendered averages of these data meaningless, IDA took the medians of each 100 successive STRIDE purchases to form a street price index.[26] This index was shown to be a well-behaved and robust statistic that clearly reveals price excursions due to source-

---

24 Crane, Rivolo, and Comfort (Ref. 6) discuss the consequences of a multiplicative pricing structure for the cocaine market.

25 The zero purity purchases were handled as if they were of very low purity to produce a finite number. This procedure will not distort the analysis because our statistic will be the median rather than the mean.

26 Although the purchase quantities varied from 0.01 gram to more than 10 kilograms, taking the median remains a valid procedure. Furthermore, the shifts in sampling volume over time were shown not to significantly alter the time series, especially over the duration of a major operation.

zone operations. Increases in the street price index are also concurrent with drops in cocaine usage according to every available indicator of cocaine consumption in the U.S. (Ref. 6; Ref. 21).[27] Figure 10 shows the street price index time series for the U.S. during the 1990's. Vertical lines indicate the beginning of interdiction operations; red lines indicate the end of the extended operations, SJ III and IV. Support to the FD/SD policy began in 1995 and is still in effect. Note that every price rise above a "floor" of about $55 was preceded by a source-zone or transit-zone operation. The price hump following the attacks on Colombian cocaine laboratories stands out particularly clearly above this floor. Even the excursion in 1999 followed the destruction of the go-fast transshipment lanes in the Western Caribbean, although these operations are not analyzed in this report.

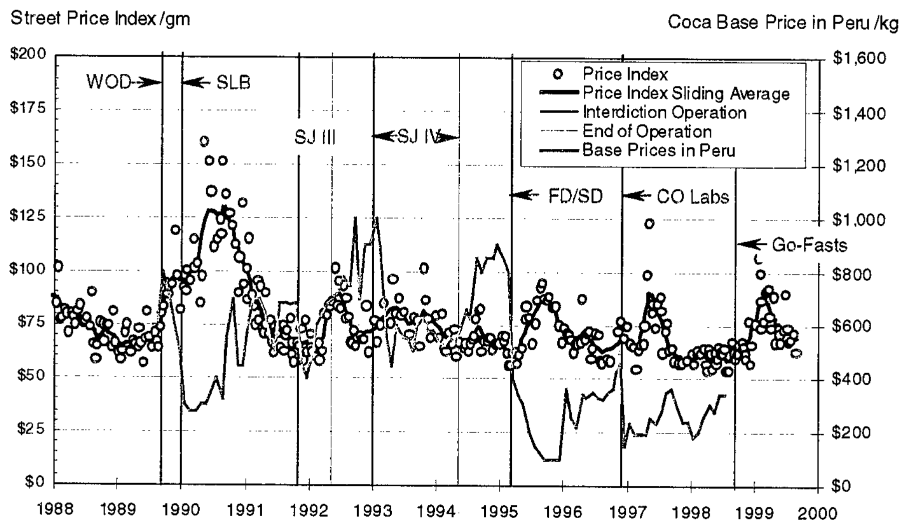


Figure 10. U.S. Street Price Index, Coca Base Prices in Peru, and Source-Zone Interdiction Operations

Overlaid on the street price index are base prices per kilogram in Peru on a scale to the right. After each major operation, Peru's base prices immediately and dramatically fell. In each case, the U.S. street price index rose abruptly 4 or 5 months later. This characteristic response in the U.S. to a source-zone shock is most clearly seen following the raids on major Colombian cocaine processing laboratories in December

---

27 Price increases of the street price index coincide with decreased use according to the following indicator data: Drug Abuse Warning Network (DAWN) emergency room reports, Drug Usage Forecasting (DUF) from drug tests on arrestees, SmithKline Beecham Clinical Laboratories (SBCL) positive test rates, and Treatment Episode Data Set (TEDS) from hospital emergency rooms.

1996 and January 1997 because this was an isolated event. Base prices in Peru fell immediately as Colombian buyers cut back purchases, and, 4 months later, the street price index rose sharply as shortages reached the United States. Notice that the index went as high as $123 per gram, but the sliding average passes below this excursion.[28] At 6 months, prices in the U.S. began to subside and by the tenth month had returned to their $55 per gram floor. Meanwhile in Peru, coca base prices experienced a minor surge, probably because Colombian buyers returned to make up the shortage.[29]

We have early findings from work in progress on a time series analysis of the street price index.[30] Essentially, the multiple air interdictions in Peru produced clearly resolvable increases of street price index, just as did the attacks on laboratories in Colombia. In all cases, the time delays before street prices rise were 5 months after Peruvian operational events and 4 months after the Colombian lab attacks. However, the street prices began to relax starting in the next month after the impact. For interdictions before the FD/SD policy, the characteristic relaxation time was only 2 months but, after the FD/SD policy, the relaxation time in Peru was 4.5 months indicating much greater pressure on traffickers.

The STRIDE data also provide enough detail to see co-movements of price for the last two or three levels of the cocaine distribution chain. Figure 11a shows the median normalized unit price calculated for three ranges of purchase quantity. Closest to the street are purchases under 10 grams, which are typically 1 or 2 grams and represent the consumer level. One-ounce quantities dominate transactions within the 10- to 30-gram range at the dealer level because the 31-gram ounce nearly always contains less than 30 grams of pure cocaine. Although purchases above 30 grams include quantities of more than a kilogram, the majority of the purchases are of a few ounces. Therefore,

---

28 The price index sliding average is a triangular weighting function spread over nine successive median values.

29 At the time of the attacks on Colombian laboratories, Peru still supplied a significant portion of the coca base destined for U.S. markets, hence the price impact on street price. Today, however, Peru probably supplies only a small fraction of the coca destined for the U.S. market, probably less than 100 metric tons of base, and Peruvian prices may no longer be as linked to Colombian shortages. (Interviews with Peru Country Teams in 1999).

30 These results were obtained using the Auto-Regressive Integrated Moving Average (ARIMA) technique. We first stabilized the time series to a stationary process and then forecasted price movement as a function of different intensities of air interdiction interceptions; see Chapter V.

this lowest price time series does not represent a full step up the distribution chain to the wholesale level of 1 kilogram.

On a compressed time scale, one can see the price excursions more clearly in Figure 11a. Although the 9-point moving average damps the full excursions in the data, one can still see that these three series appear to rise together following each indicated source-zone operation.[31] Taking the logarithm of price illustrates the similar nature of these movements as shown in Figure 11b. Because a constant percentage change is a constant increment on a logarithmic scale, the small price excursions of the series with small unit prices now appear proportional to the excursions at the street level.[32]

Similar multiplicative relationships hold in the source zone – leaf, paste, base, and cocaine prices move together.[33] However, the coca base price series in Peru are *anticorrelated* with the U.S. street price index because interdictions interrupt the flow from source to U.S. market. Beyond the point of interdiction, we believe that Colombian coca price excursions would be positively correlated with U.S. street prices, but the price data from Colombia show only that their values are comparable to prices in Peru and were never more than 90¢ above the Peruvian prices.[34] As long as Peru supplied the majority of the coca destined for the U.S. and we restrict ourselves to major operations during which trafficking continued – pre-FD/SD policy in Peru and Colombian laboratory attacks afterward – we should be able to use the approximate magnitudes of price changes in Peru as a yardstick for source-zone price impacts. On this basis, Figure 10 showed price drops of coca base during these operations in Peru of 30 to 50 percent followed 5 months later by 20 to 30 percent increases on U.S. streets. However, a 30

---

31 The data for larger quantities also show a drop and subsequent rise between SJ III and SJ IV although the smoothing function merely flattens. The final sharp rise in prices is due to the go-fast operations, which are too recent to analyze in detail for this report.

32 This was verified using ARIMA modeling to show these series do move in proportion to one another. Furthermore, the statistical scatter from month to month increases in proportion to the absolute price level, which indicates a multiplicative process and justifies taking logarithms before differences in the ARIMA process toward achieving a stationary time series.

33 PEAH data from Peru show that these time series move in conjunction with comparable multipliers for each rise and fall.

34 Colombian data sets are fragmentary and intermittent; detailed fluctuations are often inconsistent among different data sets. Nevertheless, over the period of this analysis, base prices in Colombia never exceed Peruvian prices by more than 90¢, most of which could be explained as pilot fees, bribes, and trafficker profits.

percent decrease from an average base price of \$600 per kilogram is 18¢ per gram while a 30 percent increase from an average \$60 per gram street price is \$18 per gram. If the 18¢ were an increase in Colombia, this would be a coca base to street multiplier of about 100. At most, Colombian prices could have increased 90¢, which is a multiplier of at least 20. Therefore, coca prices move dynamically and approximately proportionately at all levels in response to shocks in the source zone, which is typical of a multiplicative market structure.

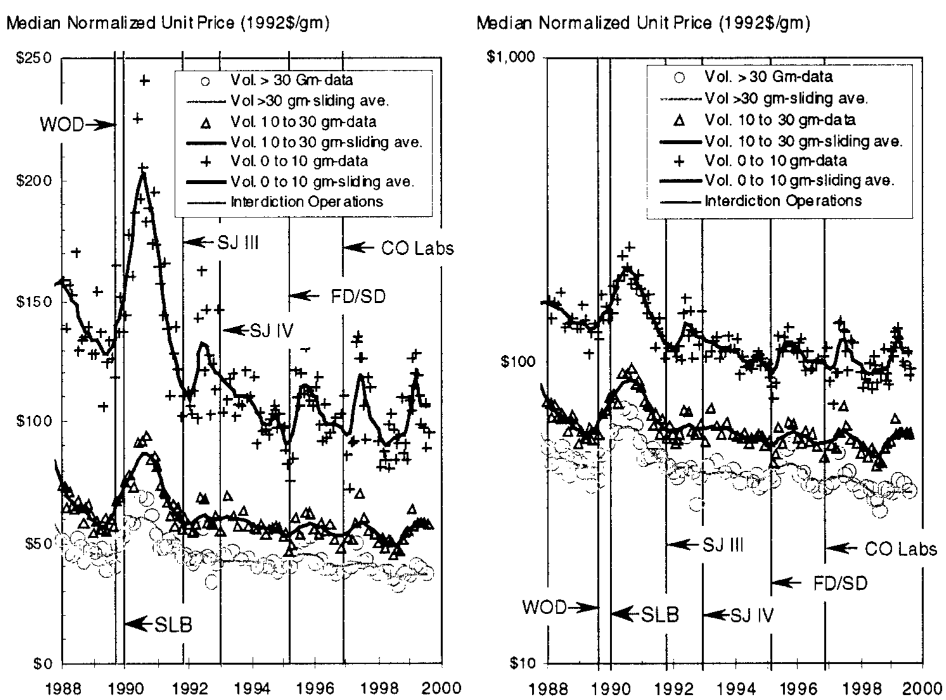


Figure 11a (linear) and 11b (semi-log). Median Normalized Unit Prices for Cocaine Purchases at Three Market Distribution Levels
Top: 0 to 10 grams; Middle: 10 to 30 grams; Bottom: 30 grams and larger.

b. Refuting the Additive Market Assumption

An \$18 per gram increase in the U.S. street price index in response to a major interdiction operation in Peru that caused only a 18¢ per gram base price increase strongly refutes the additive market assumption. The additive market assumption would have an 18¢ per gram increase in Colombian base price change the street price index of \$60 to only \$60.18, instead of to \$78.

c. Source-Zone Interdiction Impact on Casual Use

We obtained SBCL data on the positive test rate for cocaine from a broad spectrum of the American workplace.[35] These data have not been accessible to Government agencies, and the large monthly samples of more than 250,000 tests provide high-resolution information. Because these data represent persons in the workplace, the positive test rate is assumed to indicate casual use and, therefore, a much more sensitive measure of change among those with a choice rather than those with a seriously debilitating addiction. Casual users are also important because they are 80 percent of all users and are the source of future heavy users.

Figure 12 compares the SBCL data time series with the median purity of cocaine purchases from the STRIDE data set. Between 1992 and 1994, SBCL were building up their client base, and these data show increasing positive test rates as a sampling artificiality.[36] After a stable period in 1994, however, both the positive test rate for casual users and the purity of purchased cocaine show sharp declines following major interdiction operations. More importantly neither series recovered to their former levels following the enforcement of the FD/SD policy in Peru. After the laboratory attacks in Colombia, purity recovered more quickly than casual use. This suggests there is lasting damage from even short-term but large shocks.[37]

F. THE NEAR-EQUILIBRIUM MARKET ADAPTATION ASSUMPTION

More fundamental than the taxation assumption is the assumption that trafficker adaptations to source-zone counterdrug operations can be modeled by near-equilibrium balancing of supply and demand to produce a widely accepted market price and new market equilibrium. However, we found that the purpose of military operations and the types of interdiction operations described in this report act to invalidate the preconditions for such a near-equilibrium market model of trafficker responses:

---

35 SBCL, SmithKline Beecham Clinical Laboratory positive test data for cocaine were obtained by personal communication.

36 More frequent testing of individuals increases the chance of detecting those who use less frequently.

37 Again, following the most recent operations against go-fast boats, both purity and casual use showed further abrupt declines of 15 percent.

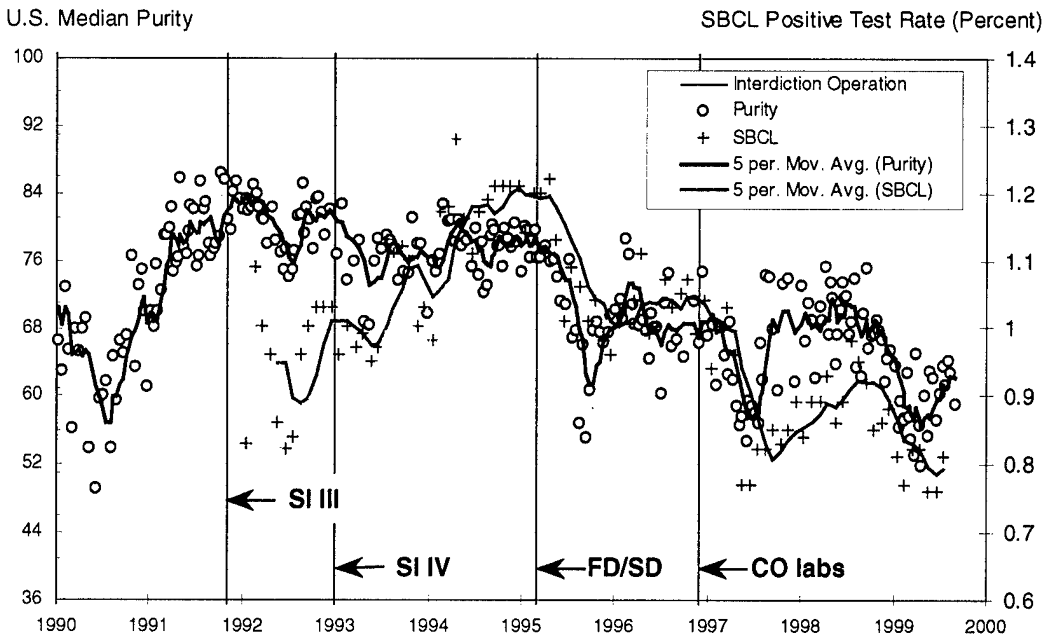


Figure 12. SmithKline Beecham Clinical Laboratories Cocaine Positive Test Rate Compared to U.S. Street Purity

- As interdiction affects one competitor more than another, it distorts the very competition and accessibility that is the basis of an overall market price. Growers and traffickers, therefore, have even fewer grounds for determining what is a "fair" price as conditions become chaotic.
- As interdiction cuts off a major supply route, traffickers must search for willing contractors with other routes – at least this leaves traffickers vulnerable to sting operations, at most, it takes the profit out of trafficking.
- As interdiction significantly interrupts the source of supply, traffickers must renegotiate the shortage all the way down the distribution chain – most likely, this exacerbates the lack of trust between buyers and sellers and may leave some traffickers without the resources to protect themselves from their enemies.
- As interdiction isolates major sources of supply from access to their buyers, it severs supply from demand – this destroys the marketplace itself and is the ultimate goal of source-zone interdiction.

Intensifying all of these interdiction-driven effects erodes the very basis of the cocaine market for traffickers at all levels. The most effective interdiction operations undermine, by their design and intent, the conditions necessary for equilibrium-market

models of drug trafficking. In this report, we analyze the responses of coca growers, smugglers, and traffickers to the extreme non-equilibrium stresses from major source-zone interdiction operations. Interdiction successes in Peru argue for the practicality of causing such disruption in the Colombian cocaine market as well as residual markets elsewhere.

This report presents analyses of the cocaine business responses to focused and coordinated source-zone interdiction operations in Peru showing that such operations can cause non-linear and severe structural disruption and market collapse. As a consequence, coca cultivation and processing have become so concentrated into localized geographic regions that *structural intervention* is even more practical than 5 years ago. From a temporal perspective, source-zone interdictions have already disrupted significant portions of the coca flows and caused equally significant price rises on the streets of the United States. Even more important, there have already been lasting purity declines for cocaine sales to end users and a decline in casual use. The repeated return of the street price index to a minimum of $55 per gram suggests there is no more margin for traffickers to reduce prices and cover the costs imposed by the risks of their business.

These counterdrug possibilities were not considered as long as everyone assumed that eradication and seizure were the only source-zone options, both of which conform to the near-equilibrium market model. But today, policy makers have designed U.S. strategies that take advantage of the inherent temporal and spatial vulnerabilities of the cocaine industry in the source zone. To be effective, these new strategies must be pursued to the point of achieving the known *thresholds* for collapse, and followed up more quickly than the typical trafficker recovery times. We know enough to use timely and meaningful measures of the damage to cocaine marketplaces to guide and sustain these operations. Such non-linear interventions could cause severe structural damage and temporal disruption to the cocaine business and, if followed up by a coherent plan of action, could lead to catastrophic collapse of the business in Colombia.

We do not claim that air interdiction or even source-zone interdiction in general is capable of destroying the cocaine business. That would require the coordination of several counterdrug efforts to exploit the sudden disruption of trafficker business as usual, and preplanned endgame options to wean national economies and those involved off their dependence on coca revenues. At minimum, the interdiction strategy should

cause significant decline of the coca business profits; at worst, it would provide more time for complementary strategies to take hold.

G. AN INTERDICTION STRATEGY FOR COLUMBIA

The results from our analysis of operations in Peru are being used in the development of an interdiction strategy intended to dismember the cocaine industry in Colombia. The following is an outline of how we would see the strategy unfold. It begins with operations against the most vulnerable and lucrative targets, sustains and follows up with continued pressure on traffickers, but puts only economic pressure on the bulk of the peasant labor supporting the cocaine business:

- The most vulnerable interdiction links are the transport vectors into and out of the cocaine production laboratories. Large cargoes of highly valuable coca product are essential if traffickers are to coordinate multi-ton movements in an insecure environment. Similar reasoning suggests that the transport of cash for payment in these large transactions is equally vulnerable. To effectively attack trafficker air routes, Colombia will have to establish tight air traffic control over both licit and illicit flights.
- Attacks on secondary transport modes and routes would keep pressure on the traffickers' critical links for coca base, cocaine, and possibly chemicals. Mapping these transport modes and routes also provides intelligence on the supply system for essential bulk chemicals and the location of major cocaine laboratory complexes. Investigating the financial institutions and dollar flows in the cocaine production regions also promises to reveal the critical nodes and trafficker organizations.
- Follow-up raids on chemical supply points and major laboratory complexes would add to the uncertainties and inefficiencies of the cocaine business, further reducing profits. Note that attempts by traffickers to disperse cultivation or cocaine laboratory operations only worsen their on-the-ground security problems and undermine processing efficiency.
- Disruption of transport routes and modes causes traffickers to seek new routes and modes generally operated by unfamiliar groups of contractor smugglers. This creates an opportunity for sting operations. Further down the distribution chain, frequent system-wide supply shortages cause middlemen to seek new suppliers, which strains the transaction negotiations already burdened by lack of trust.
- As coca base prices fall as a result these operations against coca markets, several follow-up strategies become feasible. First, the guerrillas and

paramilitaries would have less money for arms and mercenaries, which strengthens the elected government's position in negotiating a meaningful peace. Second, low coca prices lead to crop abandonment while alternative development programs support eradication of abandoned coca plants. Because these coca crops take at least a year to replace, this helps lock in the reduction of the scale of coca cultivation.

1. Forced Eradication

Continued forced eradication may be effective in the Guaviare region, but is high-risk and possibly counter-productive in the Putumayo or Caqueta regions. The Guaviare cultivation of lowland coca is already at an efficiency disadvantage as it competes with the rapidly growing Putumayo and Caqueta regions for labor, and previous forced eradication caused spatial dispersion of dense areas, further reducing efficiency. However, the risks of ground fire against eradication spray aircraft and the resentment of farm labor against the elected government may not be worth the modest tax that forced eradication could extract if extended to the Putumayo or Caqueta regions. Furthermore, aerial eradication requires large-scale operation over much of the cultivation region while air interdiction must engage relatively few undefended aircraft.

2. Trafficker Adaptation

With enough time and resources, there are risks that traffickers will find ways around static blockades or the initial tactical plans being executed. Therefore, it is essential to anticipate traffickers' next options,[38] continue to drain their resources while their business is in decline, and dismantle the weakened organizations and distribution networks when they become vulnerable. This is the essence of military-style, non-linear, far-from-equilibrium strategies that focus counterdrug operations against structural vulnerabilities of the cocaine business to undermine illicit profits and cause collapse. Peruvian successes prove these principles and demonstrate effective alternatives to the purely seizure and eradication options considered by planners based on traditional economic reasoning. By monitoring the impacts of military-style operations on the cocaine business and trafficker attempts to adapt, interdiction forces can determine the

---

[38] This was demonstrated in the 1999 operations against go-fast lanes of the Western Caribbean Sea.

intensity necessary to cause collapse and the value of sustaining interdiction pressure as trafficker activity is deterred and less prevalent.

3. Challenges to the Interdiction Strategy

Three sets of practical challenges to this strategy must be addressed. First is the need for effective support and commitment of the Colombian Government for counterdrug operations similar to that which led to success in Peru. Second is the need to prevent either the guerrillas or the paramilitaries from consolidating territorial control that would reduce their costly security and transport difficulties. Third is the need for methods to gather air traffic and coca business intelligence. Most likely, the different situation in Colombia will require somewhat different methods of intelligence and business data gathering than those used in Peru.

4. Sustaining the Pressure

The research documented in this paper suggests that effective interdiction employs attacks so sudden and broadly coordinated that trafficker networks cannot adapt efficiently. This requires capabilities the Allies have only been able to exercise a few times in the past – joint planning by the several counterdrug organizations, anticipating and engaging all principal trafficker options in a coordinated manner, and sustaining the pressure. In 1999, the joint planning and coordinating process implemented by the United States Interdiction Coordinator using these deterrence concepts had improved to a point where each counterdrug organization was able to mobilize its resources and simultaneously strike the key cocaine transportation axis in the Western Caribbean Sea. By the end of 1999 the joint operations deterred trafficker smuggling (Ref. 22) along this axis by more than 80 percent.

The deterrence strategy concept that has been tested in Peru and the Western Caribbean Sea has the potential to remove much of the income from illicit drug trafficking in Colombia from all sides – the FARC as well as the paramilitaries. Without the income from drug trafficking (estimated to be no more than 40 to 50 percent of that available in the source-zone – and reported (Ref. 23) to be about $600 million per year), it may be possible to achieve a peaceful settlement in Colombia and to address a then more tractable residual cocaine trafficking problem worldwide.

CHAPTER I

INTRODUCTION

I. INTRODUCTION

The purpose of this paper is to review and analyze the counterdrug deterrence operations executed during the 1990's against the major air trafficking routes from Peru to Colombia. We will analyze the efficacy of air interdiction and present a detailed model of the psychology of deterrence that gives air interdiction forces the leverage to shut down this essential trafficker mode. In our view, effective source-zone air interdiction is an essential first step in damaging the cocaine business. At a minimum, it heavily burdens traffickers to continue without it; at best, it causes catastrophic collapse of coca markets. To continue to be effective, however, we must continue to modernize our methods and coverage to keep abreast of innovative traffickers.

Peruvian experience from 1989 to 1998 illustrates a central vulnerability of the illicit cocaine business, and how Peruvian forces, with U.S. Government (USG) assistance, were able to exploit that vulnerability to greatly reduce the scale of illicit coca traffic to Colombia. In this report, we will explain:

- Why coca growing regions concentrate into a small portion of the land available for coca cultivation.
- Why the air bridge from growing regions and from cocaine laboratories to transshipment zones are an inherent vulnerability of the cocaine business.
- Why the psychology of deterrence enables air interdiction to be a very effective means of exploiting this vulnerability.
- Why it is important to monitor illicit coca business indicators to determine the relative success of an interdiction operation, initially in the source zone and later on the streets the United States.
- Why major source-zone interdiction operations cause significant damage to cocaine markets all the way to the streets of the United States.

Because many of these points run counter to early common misconceptions concerning illicit coca markets, we will analyze and refute these misconceptions based on the evidence presented in this report. At the end of this report, we speculate about the issues encountered in applying this successful Peruvian strategy to Colombia.

This introductory chapter provides necessary background and context. First, it describes the illicit cocaine business from farmgate to U.S. consumer. Next, it describes

the rise of cocaine production and the shifting patterns of traffic from Andean source countries to users worldwide. To provide context, it lists and discusses all of the types of counter-cocaine options in the source zone. At the policy level, this chapter identifies four key misconceptions about the effectiveness of interdiction, which the evidence in the remaining chapters clearly refutes. Those chapters are briefly oulined at the end of this one.

A. THE ILLICIT COCAINE BUSINESS

Cocaine (and its derivatives) is the most widely used illicit addictive drug in the United States.[1] The psychotropically active chemical in cocaine is an alkaloid, methylbenzoylepgonine ($C_{17}H_{21}NO_4$). It is extracted from the leaf of the coca plant by a multi-step refinement process and then distributed through a chain of middlemen until it is sold to users in the United States, Europe, and elsewhere.

Figure I-1 shows the steps of the business as a flow diagram tracing the movement of illicit coca from cultivation to end-user. From the many farmers and agricultural workers growing coca leaves on down to the cocaine laboratories, the flows progressively concentrate into larger quantities. After being processed into cocaine, the remainder of the distribution steps consists of smuggling and breaking down the quantities until they are sold to end-users in about one gram quantities. We will discuss these consolidation and distribution flows separately.

1. From Coca Farmer to Cocaine Laboratory

Coca farmers in Peru and Bolivia grow the more productive "upland" coca in Andean mountain valleys or in areas along the elevated western margins of the Amazon Basin. Colombians cultivate less productive coca varieties, "Colombian" coca in Western and Northern Colombia and "lowland" coca within the Amazon Basin itself. Although the Colombian leaf crops contain less alkaloid, their higher processing efficiencies, 70 versus 45 percent, render Colombian farms as productive as those in Bolivia and Peru.[2] Figure I-2 maps the principal growing areas in Peru, Bolivia, and Colombia in 1997. Darker greens represent denser cultivation within the designated

---

1 Cocaine hydrochloride (HCl) and its various derivatives such as "crack" are the most prevalent illicit drugs, other than cannabis, available in the United States and in Europe, behind only cannabis and amphetamine-type stimulants (ATS) (Ref. 1, pp. 91-95).

2 Revised CNC estimates for 1999 show 2.8 times more production in Colombia (Ref. 5, Colombia).

growing regions, and the arrow indicates the most direct air-bridge from Peru's Huallaga Valley to Colombia.

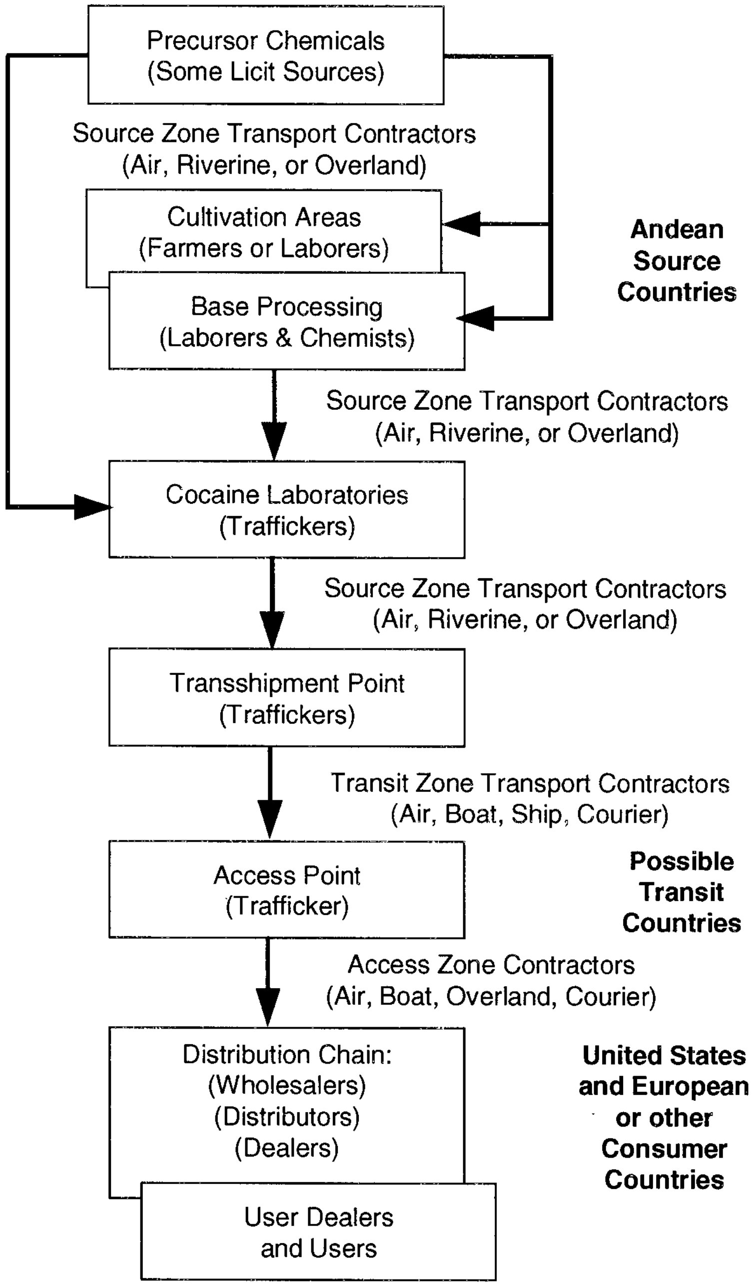


Figure I-1. Flow Diagram for the Cocaine Business

Each processing step from cultivation to processed cocaine requires labor and other inputs such as chemicals or equipment as shown in Table I-1. Although the typical processing method is described, there are several substitute chemicals and alternative

processes. All of these chemicals are common in industrial countries and have many uses; however, some of these chemicals, such as potassium permanganate, are essential to producing high-quality cocaine. Also note that each of the intermediate products have a relatively short shelf life except cocaine, which can be stored 2 or 3 years, and the batch sizes increase from a few hundred kilograms of leaf up to metric tons of cocaine at laboratories.

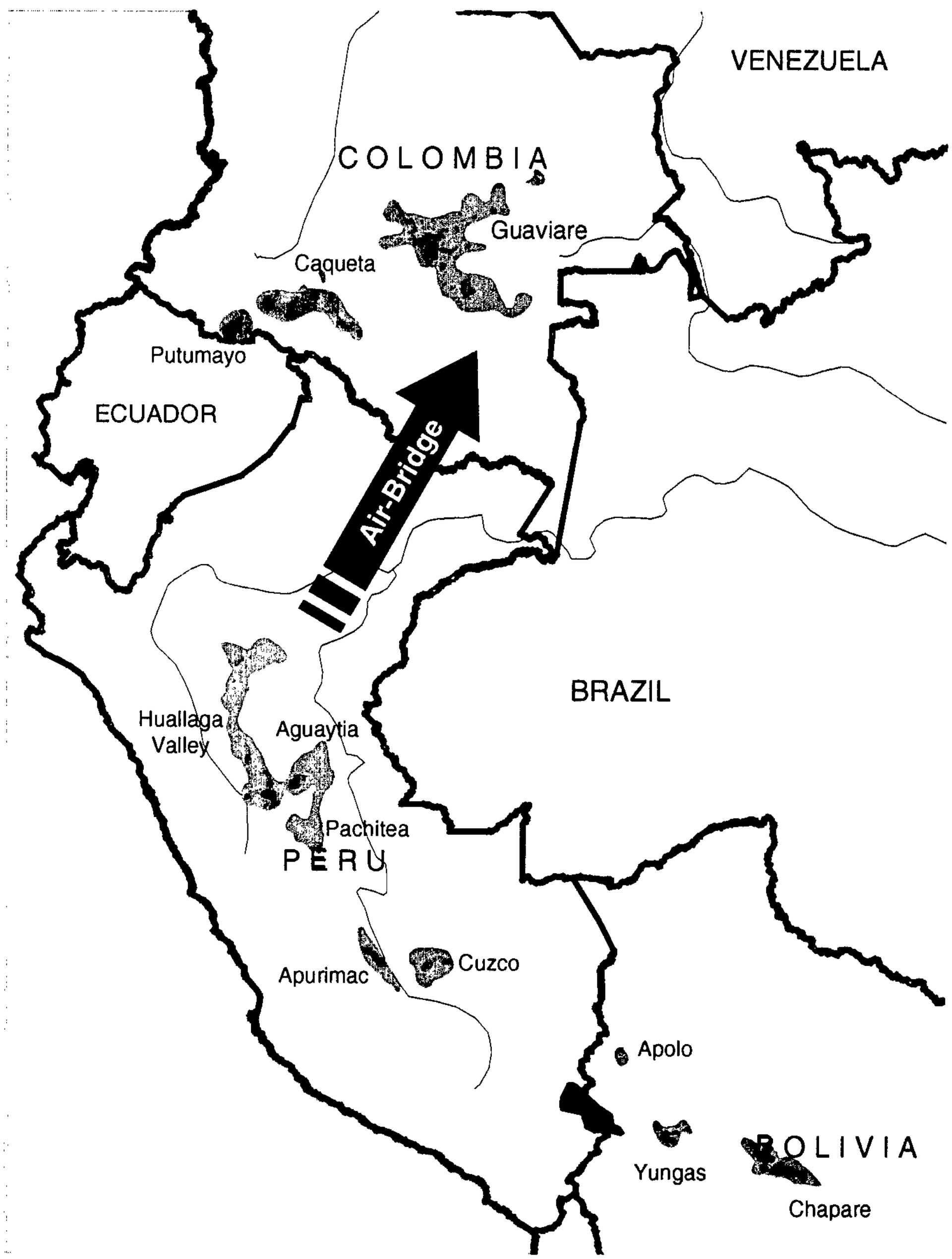


Figure I-2. Coca Growing Regions of the Andean Producer Countries, 1997

Table I-1. Coca Farming and Processing Steps to Produce Cocaine Hydrochloride

Processing Step (Shelf Life)* (Batch Sizes)	Chemicals and Inputs**	Labor and Processing***	Comments
Cultivation (Peak productivity in 7 years lasts 30 years) (2 – 4 hectares in Peru)	Herbicides (optional) Insecticides Fertilizers (optional)	Clearing the land Planting and weeding Picking leaves to aid productivity	Upland coca takes two years to be productive. Failing to regularly pick leaves reduces productivity. Jungle overgrows in 6 months to a year, but some plants can survive to be harvested as understory.
Harvesting and Drying (4 - 6 weeks dried)	None	Picking leaves 4 times a year Carrying leaves to processing point	Drying can be avoided by processing within 3 days.
Paste Production (4 – 6 weeks) (109 kg leaf – 4 kg paste)	Water, kerosene, Sulfuric acid, Sodium bicarbonate,+ lime	Digs "pozo" pit and fills with water/acid "Pisacocos" stomp leaves Precipitate with other chemicals/dry	No special skill is required. This paste is also the "bazuco" added to cigarettes and smoked.
Base Production (6 – 8 months) (42 kg paste – 20 kg base)	Sulfuric acid, ammonia hydroxide, potassium permanganate	Redesolved to remove impurities Chemist's skills needed (Early 1990's, base from paste required 1.5 kg base to make 1 kg HCl)	Potassium permanganate is critical to this step; substitute processes produce inferior product. Leaf can be processed directly to base.+ (Today 400 kg leaf for one-step base, 1 kg)
Transport to HCl Lab. (500 kg / flight)	Clandestine airfield	Pilot and aircraft, radio operator Transporters, security, accountant	Requires bribes or protection money, awareness of interdiction operations, and organization.
Cocaine HCl Production (2 – 3 Years) (Major labs > MT)	Ethyl ether, acetone, hydrochloric acid, and fuels	Skilled chemists Less skilled operators and security (Today, 1kg base makes 1 kg HCl)	There is no substitute for skill because chemicals are volatile and explosive, and the HCl must be thoroughly dried and packaged.

* Shelf-life approximations come from NAS/Peru (Ref. 24).

** Chemicals and inputs from Obdulia Gamble "Cocaine, Cultivation and Production," CNC, January 1996.

*** Labor and Processing from Cuanto SA, "Coca's Impact in Peruvian Economy, Peru 1980 – 1992," Appendix of report for USAID / Peru, September 1993.

\+ Indicated chemicals not needed for one step base production, DEA, "Operation BREAKTHROUGH: Coca Cultivation & Cocaine Base Production in Peru" (Ref. 17).

Transport from farm to paste- or base-processing points in the rugged growing areas requires manual labor. Transport of the base to a landing strip may be by river as well as overland. The journey to Colombia is long and must cross hundreds of kilometers of undeveloped mountain and jungle environment. Air transport is by far the most efficient mode because overland and riverine trafficking follows convoluted, difficult, and indirect routes, faces risks of piracy, and must avoid police interdiction.

While farmers deal in small quantities of base, traffickers assemble 500 kg or more to fly out in one or more planes, and are generally prepared to lose up to 30 percent of their loads. This requires significant financial backing and organizational coordination. A contractor team consisting of ten or fewer people including the pilot, however, does the actual smuggling. Since pilots risk their lives on every trip, they are much more readily deterred by interdiction with severe consequences.

Efficient processing of base to cocaine requires a sophisticated laboratory with a skilled chemist and extensive recycling of difficult-to-obtain chemicals. Also, for security and business reasons, laboratories must be mobile and able to process large quantities quickly. In late 1996, a few quite large laboratories processed most of the cocaine in Colombia, some with a peak production rate of over a metric ton of cocaine per day.

2. From Cocaine Laboratory to U.S. User

Laboratories may be located near growing regions, which raises the costs of bringing in chemicals and fuel, or near transshipment points, which raises the security risks. In either case, high-value coca products – base or HCl – must move from the growing areas to either a laboratory or a transshipment point, almost certainly by air. As in the air-bridge from Peru to Colombia, trafficker-owners sending and receiving the drugs hire small smuggler teams including the pilot for these flights. Similarly, small contractors smuggle drugs to access points for crossing the border into the U.S. This pattern held, for example, for go-fast boats across the Caribbean or into Mexico, drops off the U.S. East Coast and, in the west, vehicles from Mexico into the U.S. Small contractor smugglers take the transportation risks. The adaptability of this process comes from the diversity of contractors, each with unique methods and routes, rather than the ability of any individual contractor or organization to change rapidly.[3] Therefore, we

---

[3] Even trafficker "organizations" tend to be rigid hub-and-spoke networks of specialists in arranging deliveries, providing secure communications, and enforcing discipline for a central boss (Ref. 25).

expect that disruption of the smuggling pattern would force trafficker organizations to hire some less familiar contractors to replace those captured or blocked, thus creating an additional opportunity for sting operations.

Overall, during the journey from the source zone to the streets of the United States, refined cocaine passes through a distribution hierarchy that contributes very little manufacturing – only dilution, repackaging, or cooking into crack. Most of the "value added" from this distribution chain is in the effort to avoid interdiction and security threats from aggressive competitors, disloyal insiders, and interdiction forces. Table I-2 is an idealized summary of the processing and distribution steps from farm to U.S. cocaine consumer. Approximate quantities and unit prices enable the reader to grasp the relative scale of typical transactions across the steps. [4]

3. Multiplicative Market Structure

Although typical prices and quantities vary considerably at each step of the process and over time, enough is known about the transactions from farmgate to user that one can see an important pattern among these transactions. Figure I-3 plots the price-quantity relationships from Table I-2 for typical but somewhat idealized steps. Uncertainty ranges in both price and quantity represent the typical degree of variation of median values. The actual distribution of transactions, of course, includes many parallel branches creating a spectrum of values rather than the idealized steps as shown in Figure I-3.

Quantities are measured in pure grams of cocaine alkaloid, and prices are for a pure gram. Because Figure I-3 is a log-log plot, equal intervals represent equal *factors*. For example, the distance on the plot from \$1 to \$2 is the same as the distance from \$100 to \$200. The same holds for the quantity scale: the distance between each vertical line is a factor of ten, that is, from 1 gram to 10 grams is the same interval as from 1,000,000 grams, 1 metric ton (MT), to 10 metric tons.

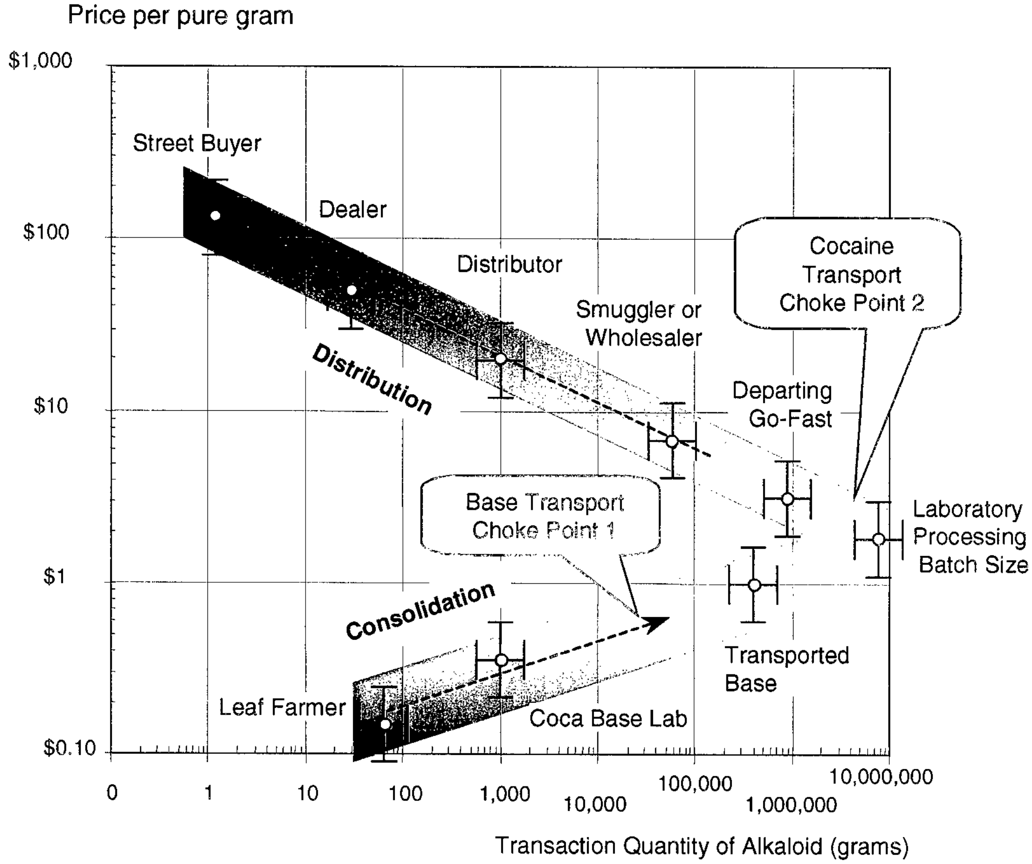
---

4 Prices and volumes for cocaine laboratories, transshipment points, and transit-zone smuggling come from private communication of police report summaries.

Table I-2. Transaction Quantities and Prices for 1998 Processing and Distribution Steps

Distribution Step	Quantity of Transaction (pure grams)	Approximate Prices for each Transaction (unit price/gram)	Comments
Leaf harvesting Selling by Arroba	11.5 kg leaf (82)	$12 ($0.15)	Although there is not much market for leaf, a few arrobas from small producers may complete a batch or add profit when base prices are up. Leaf has about 0.7 percent alkaloid
Base	2 kg base (1,600)	$800 ($0.50)	One step processes produce from one to a few kg of base of about 82 percent purity.
Transport to Lab	500 kg (400,000)	$400,000 ($1.00)	Before the air bridge was broken, it cost $90,000 to air transport to Colombia. An estimate of today's cost are about $200,000 per load.
Cocaine Laboratory	5 to16 MT (8,000,000)	$14,400,000 ($1.8)	Major growing regions produce enough leaf for about 16 MT per quarterly harvest. A few large laboratory complexes can produce all the HCl needed – many smaller labs add only a modest fraction to total production.
Transit Zone Smuggling	0.5 to 2 MT (90,000)	$2,800,000 ($3.00)	Planes and go fast boats carry about 1 MT, fishing vessels about 4 MT as would container freight. Trucks through Central America might carry 100 to 500 kg. During low stress, shipped cocaine is 85 to 90 percent pure.
Access Zone Smuggling and Wholesaler	30 to 150 kg (60,000)	$400,000 ($6.60)	These volumes are about the typical size of cross-border smuggling, which ranges widely. It also characterizes the mid-level distributors loads in the US.
Distributor	500 gm to 2 kg (1,000)	$19,000 ($19.00)	Local wholesalers typically buy 1kg quantities, grind up the bricks, dilute the powder about 10 percent, and resell in ounce quantities.
Dealer	0.5 to 2 oz (30)	$1,500 ($50)	Dealers purchase an ounce or so, dilute it about 10 percent, and resell it in gram or partial gram quantities. Crack dealers cook the cocaine into hard nearly pure crystals and resell in rocks or vials.
Consumers or Consumer/Dealers	0.07 to 5 gm (1.0)	$140 ($140)	Users and buyers range widely in consumption and transaction amounts. The median user may consume a gram per year, but most consumption is by heavy users absorbing over a gram per week. Some of these are user-dealers, who pay for their heavy use by selling to others.

The striking feature of the cocaine business in Figure I-3 is the uniform progression of price increases first as quantities of alkaloid concentrate from farmgate to cocaine laboratory and then as they distribute from laboratory batches to street purchase quantities (Ref. 6). This uniform progression results from a constant markup relative to a given number of sales. Typically, a trafficker in the cocaine distribution chain buys a quantity, Q, at unit price, p, and sells to 30 customers an amount, $Q/30$, at unit price 2.5 x p. For this, the trafficker receives 2.5 – 1 = 1.5 times their investment, no matter which quantity Q or unit price p they dealt along the distribution chain.[5]



Sources: All STRIDE in U.S. (Ref. 20), various for Colombia, 1998 UNDCP Peruvian Leaf and Base (Ref. 26).

Figure I-3. Price-Quantity Relationship for Steps in the Cocaine Business

---

5 This markup value changed very slowly between 1983 and 1998. The value of 2.5 is reasonable for the 1990's, while previous work gave a larger value that included data from the 1980's (Ref. 6).

a. Risk Sharing and Cost of Distribution

This uniform progression can be understood from two different perspectives – balancing risks and profits among the steps or equal return on investment. Balancing risks means that traffickers come to understand the profitability of steps above and below them are the same as their own. If an adjacent step were to become more profitable, over time traffickers above and below would encroach to equalize its markup profitability. The alternative explanation, equal return on investment, derives from traffickers expecting to get a standard markup on their at risk capital for any step in the chain. During the period from 1995 through early 1999, the idealized distribution chain marked up prices 2.5 times for each step assuming that traffickers break down a load and resell to approximately 30 customers. These high markups reflect the high risks and large losses along the distribution chain. Roughly half of the cocaine does not successfully make the trip from laboratory to street. This would translate into an average 15 percent loss at every step in the transaction hierarchy shown in Figure I-3.

We have examined the dynamic response of the distribution chain to cost and price impacts using the available data from the source zone – leaf, paste, base, and HCl prices, and from the last two and one-half steps of the U.S. distribution system – volumes of about 100 grams down to fractional grams. Both sets of data show proportional price swings at all levels; we show these results for the U.S. distribution system in Chapter V.

Chapter V also shows that during the 1990's constant dollar prices tend to return to a common floor following each disruptive increase. We *conjecture* that this constant floor represents the minimum profits that traffickers in the distribution system must receive to continue to take the risks in this dangerous business. User demand appears sufficiently elastic to adjust to whatever supply is available at this floor price. Chapter V also shows that purity has systematically declined following major disruptive operations. Thus, purity may be a more revealing indicator of the stresses on the cocaine business.

These findings suggest several important questions that warrant further analysis beyond the scope of this report:

- How are profits and risks adjusted among several independent levels of transactions? If source-zone operations against a choke point increased prices there by a large factor, how would the markup factors adjust in subsequent levels?
- Can traffickers maintain a constant cash flow during shortages by increasing real prices on their limited supplies?

- Why do prices return to a constant "floor" of about $55 to $60 following transient increases caused by major interdictions? Might this represent a minimum fee necessary to cover the minimum costs of distribution risk, and how does supply and demand relax to a new balance point at the same price?
- If the progression of markups represents the degree of risk for each step, can this progression reveal opportunities for interdiction? Can different responses be seen for different parts of the United States indicating different market structure and cause to shift strategies?

b. Exploiting Concentration at Cocaine Laboratories

Laboratory refinement of cocaine HCl is the most concentrated step in the entire business process. Although there were many such laboratories in 1997, the largest few could refine the total quantity necessary to satisfy the entire U.S. consumption. Larger laboratories appear to be more efficient and also may enable major cocaine trafficker organizations and Colombia as a whole to control the great majority of the cocaine market from this key step. Note that the large laboratory depicted in Figure I-3 could process the entire harvest for a major coca growing region, in four batches the entire production of a region for a year, and 10 such laboratories all of Colombia's production. By contrast, the fragmented smaller laboratories in Bolivia, operated in some cases by families or farmers, have difficulty getting the supplies and equipment to produce a quality product. Their inferior product sells for much less, and coca production declined sharply in 1998 and 1999. This may be the fate of any attempt to process large amounts of cocaine in many distributed small-scale laboratories.

Other points of geographic concentration are the growing regions.[6] Therefore, transportation from growing regions to cocaine laboratories must concentrate at both ends. Transportation from laboratories to transshipment points is probably also concentrated because major traffickers control distribution to and from both these activities. Because these transport links are over rugged and lawless terrain, traffickers are virtually compelled to use aircraft. Detection and monitoring of these flights provides an interdiction opportunity to engage traffickers at an inherent choke point in the cocaine business. Interdiction at this choke point can engage the bulk of all cocaine flows to either shut down large portions of the industry or to continually disrupt it to the degree that all other links become more vulnerable.

---

6 See Chapter II, which explains that cultivation concentrates in dense zones and this concentration appears to be increasing with interdiction stress.

Attacks against these air-bridges engage traffickers rather than a peasant population of farmers and laborers. Although trafficker organizations are willing to suffer losses upwards to 30 percent of their loads,[7] pilots are deterred by sustained interdiction rates of less than 3 percent[8] if there are severe enough consequences. Explaining the inherent nature of this vulnerability and the practicality of deterring pilots flying these essential air-bridges is another aspect of the central purpose of this report.

B. FLOWS OF ILLICIT COCA PRODUCTS

An overview of the flows of illicit coca products completes the context for the remaining chapters and introduces many of the uncertainties confounding analysis of these subjects.

1. Coca Cultivation Timeline

Before the cocaine epidemic, there was a relatively constant level of licit coca cultivation and some diversion into a small population of illicit users. From 1970 to 1979, Peru grew about 17,000 hectares[9] (ha) (Ref. 27; Ref. 28; Ref. 29) and Bolivia grew about 7,000 ha of coca for licit internal consumption, foreign trade, and a small level of illicit use. As the cocaine epidemic grew, Peru rapidly became the principal supplier of illicit coca derivatives as Figure I-4 clearly illustrates.

Early data sources on cultivation were in agreement until the cocaine epidemic after which estimates varied widely (Ref. 27; Ref. 29). From 1986 through the early 1990s, the International Narcotics Control Strategy Report (INCSR) and National Narcotics Intelligence Consumers Committee (NNICC) report periodically revised earlier estimates and did not always agree with one another, although these differences were not operationally significant. Since the early 1990's, satellite surveys have provided sufficiently accurate estimates to make accurate year-to-year comparisons (Ref. 5). However, there remain differences of opinion about the quantities of coca grown in dispersed areas not covered by the satellite surveys.[10]

---

7 See Appendix A for incarcerated trafficker interview results to this effect, and Chapter IV for operational results from Peru.

8 See Chapter IV.

9 A hectare is 1/100th of a square kilometer and is also 2.471 acres.

10 Private communication with UNDCP offices and U.S. State Department observers, and UNODCCP (Ref. 1).

In the 1980s, prices were so high that all of the coca products – leaf, paste, base, and of course cocaine could easily be sold independently at a profit, and Peruvian farmers planted over 100,000 ha of new coca. However from 1989 to 1992, supply had overtaken demand and President Bush's "War on Drugs" combined to depress profit margins and stop further net cultivation increases. At that time in Peru, most farmers cut out middlemen by bringing in chemists to process leaf directly to base.

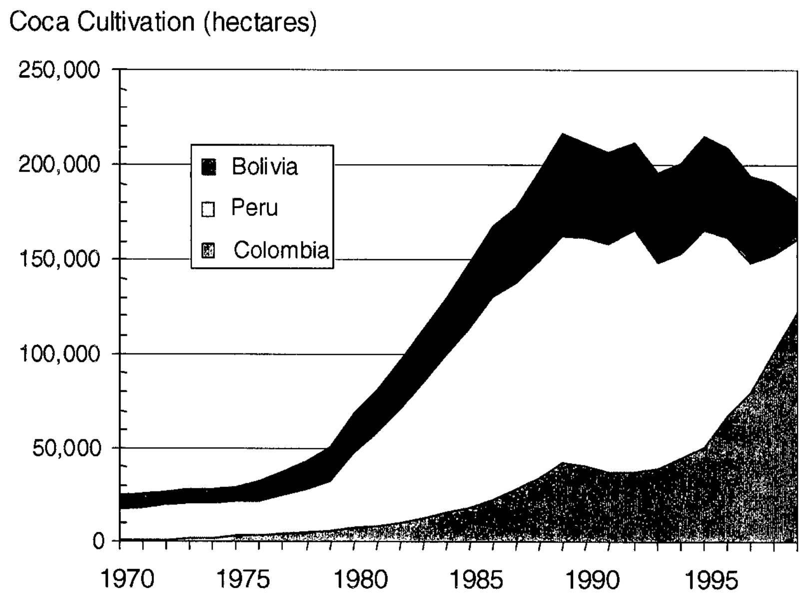


Figure I-4. Coca Cultivation for Colombia, Peru, and Bolivia (in hectares)

In 1995 with prices very low due to the collapse of the air bridge, Peruvian farmers abandoned their crops and fields in large numbers. Only in 1999 has this trend bottomed out. Remaining Peruvian production is believed to have split between residual traffic to Colombia and an increasing fraction diverted toward the European and the oriental markets to replace Bolivian coca.[11]

While we were preparing this report, the collapsing markets in Peru and Bolivia finally reached a new, lower balance of supply and demand. Prices in these two countries began to rise after their long plummet. This illustrates two points. For certain, there are eastern and western routes from these two countries not sufficiently covered by interdiction forces. Second and less certain is the emergence of a new pattern of supplier-consumer nations. It appears that much of Peru's residual production diverted to Europe

[11] Interviews with DEA, NAS, and other U.S. embassy personnel.

and the Orient as Bolivia's declined. Subsequently, lower quality Bolivian coca found major markets in Brazil, and at a reduced level maintains a smaller portion of the European market. Also, a much smaller but unknown fraction of Peru's production still leaks northward to Colombia or is refined to cocaine in-country and sold directly the Mexican traffickers.

All evidence suggests that since the War on Drugs, Bolivian production has gone toward satisfying licit internal consumption, Europe, and Brazil, but not to the United States. For example, as Peruvian prices rise and fall significantly, as shown in Chapter III, the Bolivian prices do not react as one would expect if Colombian buyers were shifting to an alternative source of supply. Furthermore, there is no evidence from chemical analysis of U.S. street samples that they came from Bolivia. More recently, reports suggest that this remains true and Bolivian coca processing quality has fallen to the degree that its export quality products are not competitive in either Europe or the orient without expensive reprocessing.[12]

Farm size and organization contrast the differences in the cocaine agriculture among the three producer countries. In Peru, family farmers grow about 2 to 4 hectares of coca along with fruits and vegetables for their own consumption. In Bolivia, the farms are about the same size but terraced to reduce erosion and remain productive longer. In Colombia, by contrast, farms are generally much larger, up to 17 ha, and often organized as an agribusiness with hired farm labor.

Starting in 1994, Colombian traffickers began increasing cultivation in their more upland regions. This may have been in response to newly felt price rises from pilot fees for flying coca base from Peru during Support Justice IV or an anticipation of the vulnerability of the air-bridge to more concerted interdiction. Nevertheless according to the best current estimates, Colombians were not able to fully replace the lost Peruvian crop until possibly 1999.

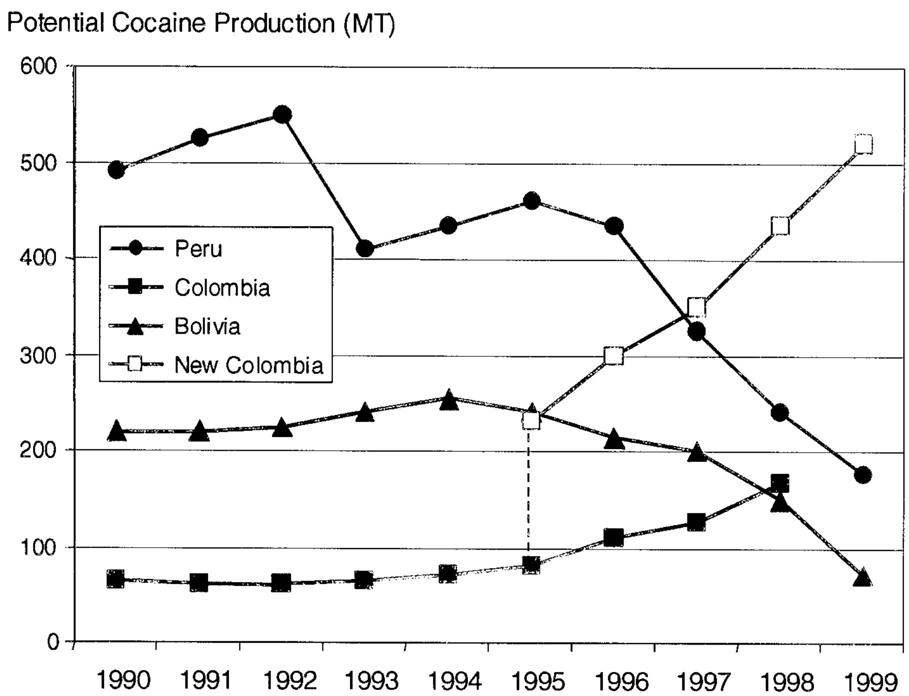
2. Cocaine Production Timeline

Estimates of cocaine production are less certain than the cultivation because cocaine estimates are based on factors less well understood. As coca moves along the distribution chain, uncertainties arise in weather and agronomy crop yield, controversial eradication losses, reporting problems in tabulating seizures, unreported abandonment

---

[12] Personal communication from DEA in U.S. Embassy in Bolivia.

due to risks, spoilage, processing efficiencies, and poorly mapped routes and destinations. These uncertainties conspire to thwart accurate mapping of flows. For these reasons when we address flows beyond the source zone itself, we avoid analyses that depend on the aggregate quantities of flows and, instead, we use intensive measures such as price, purity, and chemical composition. That said, Figure I-5 shows the estimated potential cocaine production of the source nations based entirely on cultivation estimates and productivity ratios (Ref. 5).



New Colombia: CNC revised their production estimate upward in 1999 by a factor of 2.8.

Figure I-5. Potential Cocaine Production

The key points to notice are that Peru and Bolivia have declined sharply, that Colombian production began to take off in 1994, and that Colombian production probably exceeded Peru's since 1997. In early 1999, the CNC revised their estimates of Colombian potential after learning that the new Putumayo and Caqueta cultivation was a more productive variety of coca plant (Ref. 30). Again in late 1999, CNC had additional information on leaf alkaloid content harvest size, and processing efficiencies of 70 percent versus 45 percent for Peru and Bolivia (Ref. 5, Colombia, 1999). Apparently, the

number of harvests and leaf alkaloid content imply that lowland coca is actually more productive than the "Colombian" coca grown in Putumayo and Caqueta.[13]

3. Worldwide Distribution

The demand for illicit coca products has spread worldwide. Although much of the consumption in Brazil and South America is of lower quality than the refined cocaine sold to the U.S., Europe, and wealthy oriental countries, the total consumption contributes to sustaining the traffickers everywhere. We scaled published prevalence in each country by their national population and assumed that consumption per user was comparable to that in the U.S. to obtain an overall estimate.[14] Our total was plausible, and the U.S. fraction was almost exactly one quarter of the world estimate. If three quarters of the world's consumption is in other markets, their epidemics and tastes will cause additional fluctuation in source countries and warrant expansion of future analyses.

C. COUNTERDRUG OPTIONS IN THE SOURCE ZONE

Counterdrug operations have employed many different options in the source zone either individually or in combination. The most common options are the following:

- Eradicate crops
- Create attractive licit alternatives for those otherwise drawn to coca business
- Prevent movements of precursor processing chemicals or coca products
- Seize precursor processing chemicals or coca products
- Seize or destroy production laboratories
- Block money laundering or seize assets
- Counter those people or organizations that protect the illicit coca business.

Each of the three Andean countries took a different approach to crop eradication, but we tend to favor voluntary eradication in conjunction with alternative development. When the coca business is in decline, alternative crop programs or attractive business alternatives act to increase security, reduce violence, make illicit activity more difficult to

---

13 The CNC report 4.7 metric tons of wet leaf per hectare with 0.149 percent alkaloid content, which yields almost as much cocaine per hectare as Peru and Bolivia in recent years (Ref. 5, Colombia, 1999).

14 Based on prevalence estimates in UNODCCP and national populations. The UNODCCP report (Ref. 1), however, states that with less reliable world data, they estimate the U.S portion to be closer to one-third world demand.

conceal, and further shrink a declining coca sector. While placing eradication and alternative development in a category of endgame strategies, this report focuses on how to cripple a robust coca business.

As the central topic of this report, we argue that attacking the transportation sector – especially air transportation – strikes at a choke point. Focusing on transport engages an essential and exposed activity that also reveals intelligence about the key locations of laboratories and transshipment. Air interdiction, and to a lesser degree on riverine or overland interdiction, block movement by deterring pilots or smugglers. If this is done with the threat of severe consequences, interdicting a few is enough to deter most of the rest. Moreover, the traffickers, rather than the host government, are blamed for the collapse of the coca revenues that farmers and laborers have come to depend upon.

Other counterdrug options in the source zone are peripheral to this report, and we mention them only as they affect the core argument. Seizure of materials has yet to achieve a level that damages the coca business, but capture and imprisonment of traffickers can contribute to deterrence. While we do not address money laundering and only briefly mention seizing assets, we do address the economics and investment stakes in coca. Finally, fighting revolutionaries or paramilitaries is primarily an internal security challenge for the source-zone countries and not an area for direct U.S. involvement. However, when such factions draw their resources from cocaine trade or prevent indigenous national police from controlling the illicit cocaine business, source country and U.S. interests coincide. Thus, we must also indirectly address how our counterdrug efforts impact the source-zone nation's national sovereignty and political stability.

D. MISCONCEPTIONS ABOUT INTERDICTION

This report focuses on how to damage the cocaine business and analyzes the street price impacts of source-zone interdiction operations; however, our results contrast sharply with what has been the prevailing understanding of economics of drug enforcement. In a classic paper on that subject, Reuter and Kleiman (Ref. 2) articulated a perspective that became the common wisdom and influenced counterdrug policy and planning. It is valuable to revisit that paper and its misconceptions about interdiction in the light of subsequent experience and the evidence from major source-zone operations described in this report. This close examination will refute four of the key assumptions underlying this early work and its assessment of alternative drug enforcement policies.

1. Four Common Assumptions

In 1986, Reuter and Kleiman analyzed the illicit drug business and the efficacy of drug enforcement using the tools of economic analysis (Ref. 2).[15] A few quotes capture the core of their argument and its underlying assumptions:

> "Retail price can be used as a measure of effectiveness, for these [drug law enforcement and source control] programs can reduce use only by making drug dealing, including production and importation, so risky that dealers will require higher compensation for continued participation" (Ref. 2, p. 296).
>
> "Throughout this analysis we assume that drug markets are competitive. ... This assumption is critical to the analysis since the response of markets to a tax is determined by their structure" (Ref. 2, p. 301).
>
> "There will always be as much of a drug physically available at the export point as U.S. customers are willing to purchase at the risk-determined retail price" (Ref. 2, p. 298).
>
> "Our results are simply stated, Federal enforcement efforts have great difficulty in imposing significant costs on mass-market drugs. The sheer size of the markets forces a concentration on crops in the field, export-import transactions, and high-level domestic dealing. However, these components of the production-distribution process account for a modest share of the final retail price of the drugs; about one-quarter for marijuana and one-tenth for cocaine. Thus, even if the federal effort were to succeed in raising the kilogram-level price of cocaine or the ton-level price of marijuana, this would have limited effect on the retail price" (Ref. 2, p. 290).

There are four assumptions concerning source-zone interdiction embedded in this line of reasoning that are refuted by the evidence and analyses in this report:

- The *taxation assumption* asserts that all interdictions in the source zone consist of eradication of coca plants or seizure of coca products[16] and related

---

15 Wisely, Reuter and Kleiman stated many caveats realizing they were treating a very broad subject from a single disciplinary perspective; unfortunately, these caveats and assumptions have been forgotten and not revisited. "Some caveats to this analysis should be mentioned. We focus on the consequences of enforcement for price because that is the only element of the markets that is much affected by most of the enforcement activities with which we are concerned," and "We work with even more than the average number of assumptions used in economics because the available data on illicit drug markets are so meager [in 1986]."

16 Only crop eradication and seizure of cocaine moving in the pipeline to the U.S. were analyzed as source-zone interdiction options.

materials and, therefore, these losses merely "tax" the traffickers with additional overhead costs.

- The *expansion assumption* asserts that traffickers can always cultivate more coca either in established or new regions to replace losses to interdiction and law enforcement. Furthermore, this cultivation will be sufficient to satisfy all U.S. demand and, implicitly, European and worldwide demand as well.
- The *additive cost market assumption* asserts that even if source-zone operations cause source-zone prices to increase by a significant fraction of their former levels, this would not have much impact on the illicit drug business because source-zone costs are a very small fraction of the ultimate street price of the drug.
- The *near-equilibrium market adaptation assumption* asserts that all forms of drug enforcement in the source zone are absorbed by the adaptive mechanisms of competitive market dynamics, which overcomes these disruptions by readjusting flows and prices to a new and implicitly viable market equilibrium.

If true, these assumptions would imply that source-zone interdiction was a poor investment of resources and in some cases counterproductive. As recently as 1996, Riley argued exactly that, "source country control law enforcement strategies cannot be meaningfully linked to deterring drug trafficking behavior, and consequently they cannot be linked to the ultimate goals of reducing cocaine use." (Ref. 3, p. 260)

The evidence and analyses presented in this report directly refute Riley's conclusion and each of the four assumptions from Reuter and Kleiman. However, simply knowing that these assumptions did not hold in Peru does not ensure success in future source-zone counterdrug enforcement. As we will see, the key distinction between the successful interdiction operations in Peru and the above common view is in the type of actions and their pace, scope, and dynamics.

Policies of gradual harassment of this or that component of the illicit cocaine business leave intact all but one of the common assumptions.[17] By contrast, concerted pressure applied at choke points of the cocaine business negates these assumptions. And, if followed up by exploitation of the inflexibilities in the cocaine business, such a chokehold might even cause catastrophic collapse of the source-zone coca market. Once diminished to a lower scale and profitability, residual source-zone coca markets become

---

[17] The evidence does not support the *additive cost market assumption* even if counterdrug operations only relied on gradual harassment.

amenable to several endgame strategies leading to replacement by the licit economy and legitimate social order.

We now summarize how the findings of this report specifically refute each of the four assumptions.

2. The Taxation Assumption

Chapter IV will show that air interdiction against trafficker flights can be so intimidating that it deters all but a few pilots. Chapter III shows that even offers of extraordinary fees to pilots cannot induce sufficient numbers to continue the trafficking. With the access to market choked off, the source-zone market collapses as prices plummet, fields are abandoned, and the local economy weans itself from coca revenues. The taxation assumption does not include the possibility for wholesale abandonment of essential transportation links because it implicitly asserts that fee increases can overcome all obstacles. Moreover, the taxation assumption implies that shortage should cause coca base price increases in source zones but, in Peru, prices dropped so low that fields were abandoned.

3. The Expansion Assumption

Chapter II will show that the collapse of Peru's production led to even more concentration into Colombia's most concentrated regions rather than dispersion to many regions or other countries. Since the Reuter and Kleiman paper, even the small Brazilian coca areas they refer to have virtually disappeared, and the only other Amazon Basin region growing lowland coca is in Colombia and is declining. Although, Colombia has been able to largely replace the lost cultivation in Peru, its expansion has not yet increased the worldwide supply. Moreover, the compact growing areas of Colombia should be vulnerable to the same strategy pursued in Peru – air interdiction of coca flights from concentrated growing regions to cocaine laboratories – or from labs to transshipment points.

If Bolivia is a model, the dispersal of cocaine processing to many small labs undermines process efficiency and product quality. Also, the less centralized business was less able to corrupt high-level officials, lost popular support, and became vulnerable to new types of interdiction and alternative development. The concern is whether the government has the resources to effectively police the residual smuggling avenues to keep prices low.

4. The Additive Cost Market Assumption

Section A.3.a of this Chapter described the observed risk and profit sharing structure of cocaine market distribution at all levels, and Chapter V describes the price dynamics from source to user in this market and among its levels. This observed structure implies that cost increases at one level are passed on to other levels as a percentage rise rather than as a fixed increment. In other words, prices at all level of distribution are *multiplied* by a factor in proportion to the percentage increase in the source zone. Due to the extreme concentration of flows in the source zone, interdiction has the potential to create vast shortages that can increase prices on U.S. streets by comparably large factors. This is the observed *multiplicative market* dynamic, which contradicts the additive cost market assumption.

5. The Near-Equilibrium Market Adaptation Assumption

More fundamental than the taxation assumption is the assumption that trafficker adaptations to source-zone counterdrug operations can be modeled by near-equilibrium balancing of supply and demand to produce a widely accepted market price and new market equilibrium. However, we found that the purpose of military operations and the types of interdiction operations described in this report act to invalidate the preconditions for such a near-equilibrium market model of trafficker responses:

- As interdiction affects one competitor more than another, it distorts the very competition and accessibility that is the basis of an overall market price. Growers and traffickers, therefore, have even fewer grounds for determining what is a "fair" price as conditions become chaotic.
- As interdiction cuts off a major supply route, traffickers must search for willing contractors with other routes – at least this leaves traffickers vulnerable to sting operations, at most, it takes the profit out of trafficking.
- As interdiction significantly interrupts the source of supply, traffickers must renegotiate the shortage all the way down the distribution chain – most likely, this exacerbates the lack of trust between buyers and sellers and may leave some traffickers without the resources to protect themselves from their enemies.
- As interdiction isolates major sources of supply from access to their buyers, it severs supply from demand – this destroys the marketplace itself and is the ultimate goal of source-zone interdiction.

Intensifying all of these interdiction-driven effects erodes the very basis of the cocaine market for traffickers at all levels. The most effective interdiction operations

undermine, by their design and intent, the conditions necessary for equilibrium-market models of drug trafficking. In this report, we analyze the responses of coca growers, smugglers, and traffickers to the extreme non-equilibrium stresses from major source-zone interdiction operations. Interdiction successes in Peru argue for the practicality of causing such disruption in the Colombian cocaine market as well as residual markets elsewhere.

This report presents analyses of the cocaine business responses to focused and coordinated source-zone interdiction operations in Peru showing that such operations can cause non-linear and severe structural disruption and market collapse. As a consequence, coca cultivation and processing have become so concentrated into localized geographic regions that *structural intervention* is even more practical than 5 years ago. From a temporal perspective, source-zone interdictions have already disrupted significant portions of the coca flows and caused equally significant price rises on the streets of the United States. Even more important, there have already been lasting purity declines for cocaine sales to end users and a decline in casual use. The repeated return of the street price index to a minimum of $55 per gram suggests there is no more margin for traffickers to reduce prices and cover the costs imposed by the risks of their business.

These counterdrug possibilities were not considered as long as everyone assumed that eradication and seizure were the only source-zone options, both of which conform to the near-equilibrium market model. But today, policy makers have designed U.S. strategies that take advantage of the inherent temporal and spatial vulnerabilities of the cocaine industry in the source zone. To be effective, these new strategies must be pursued to the point of achieving the known *thresholds* for collapse, and followed up more quickly than the typical trafficker recovery times. We know enough to use timely and meaningful measures of the damage to cocaine marketplaces to guide and sustain these operations. Such non-linear interventions could cause severe structural damage and temporal disruption to the cocaine business and, if followed up by a coherent plan of action, could lead to catastrophic collapse of the business in Colombia.

We do not claim that air interdiction or even source-zone interdiction in general is capable of destroying the cocaine business. That would require the coordination of several counterdrug efforts to exploit the sudden disruption of trafficker business as usual, and preplanned endgame options to wean national economies and those involved off their dependence on coca revenues. At minimum, the interdiction strategy should cause significant decline of the coca business profits; at worst, it would provide more time for complementary strategies to take hold.

E. OVERVIEW OF THIS REPORT

The core chapters of this report, II through V, present several interrelated analyses supporting one central point: air interdiction of trafficker flights from Peru to Colombia proved to be a vulnerability of the illicit coca trade between those countries. To bolster this point, it describes and analyzes the situation before, during, and after the successful interdiction blockade of the air-bridge from Peru to Colombia

This report contains many analyses and associated calculations. In order to assist interested readers who desire to follow these calculations, we have often reported more digits than may be statistically significant. These additional digits do, however, provide clues about the form of our calculations.

Chapter II: Concentration of Illicit Coca Cultivation

This chapter analyzes the concentration of coca cultivation and finds that it results from transportation constraints. Consequently, there are no good alternatives to air transportation to take coca base from Peru to Colombia. It also shows that under stress, cultivation areas have been concentrating even more rather than dispersing. A final subsection addresses the expansion assumption.

Chapter III: Vulnerability of Air Transport

This chapter defines a major interdiction operation and introduces the "interdictor's dilemma." To know that the decline in trafficker flights is truly damaging the coca base market enough to warrant sustaining an operation while few traffickers continue to fly, interdictors must monitor the coca market indicators. Primarily these are coca base prices, and others are collateral information such as abandoned fields and depressed coca region economies. It then explains the economics of coca base production in Peru, and relates coca base price to likely farmer decisions to plant more coca, to merely maintain what they have, or to abandon their fields as uneconomical. Such a market indictor provides a basis for resolving the interdictor's dilemma – determining whether an operation is damaging the coca base markets. With this market indicator, the chapter describes the major air interdiction operations and the many collateral events affecting Peru and its coca market price. From this, one sees that the only coherent, consistent, and generally accepted cause of coca base market collapse in 1995 and onward was air interdiction. Traffickers depend upon air transport contractors to get coca base from the growing areas to either cocaine laboratories, and interdiction

operations denying these air routes to traffickers isolates the coca base market from its buyers causing a price collapse.

Chapter IV: Deterrence of Traffickers

This chapter analyzes and mathematically models the psychology of deterrence. We draw evidence from interviews with incarcerated smugglers, the academic literature on the psychology of risk taking, and data from actual interdiction operations to validate and calibrate this model. From this, we find thresholds below which traffickers ignore the interdiction risks but above which they rapidly quit. For various consequences of being intercepted, the calibrated model provides estimates of these deterrence thresholds as percentages of flights that must be intercepted. Thus, we find that interdicting only a small percentage of trafficker flights, 3 to 13 percent, with the threat of severe consequences is sufficient to deter over 80 percent of the other trafficker pilots from flying. Because air traffic is readily detected and monitored and a small air force can achieve the necessary rate of interdiction, this strategy was practical for the Peru to Colombia routes.

As a final comment, this chapter explains that the non-linear structural change caused by crossing a deterrence threshold invalidates the taxation model as a universal representation of the impact of interdiction on the cocaine business.

Chapter V: Impacts on the U.S. Cocaine Market

This chapter shows the significant rise in U.S. street price, decline in purity, and decrease in casual use following the major source-zone interdiction operations. It also gives highlights of formal time series modeling work in progress quantifying these associations between source-zone interdiction and street price increases. To complete the representation of the multi-level multiplicative market introduced in Subsection A.3.a above, Chapter V shows the dynamic proportional movement of the prices for final three levels of cocaine distribution in the United States. Again, we mention time series modeling work in progress quantifying these proportional movements. Altogether, these analyses present a coherent end-to-end dynamic model of the cocaine business. Each level of interdiction and law enforcement contributes to the risk and price multipliers, which compound to price many would-be users out of the market for cocaine.

These results complete the resolution of the interdictor's dilemma by showing that, although delayed by 4 or 5 months, source-zone interdiction does have a significant

impact where it counts – on U.S. users. These findings also complete the presentation of evidence contradicting the additive model of cost impacts due to interdiction.

Chapter VI: The Strategy for Colombia

The last Chapter speculates about the future relevance of lessons from Peru, especially, the uncertainties and differences to consider in transferring this successful strategy to Colombia.

CHAPTER II

CONCENTRATION OF ILLICIT COCA CULTIVATION

II. CONCENTRATION OF ILLICIT COCA CULTIVATION

The distribution of illicit coca cultivation, as with most economic activities, is subject to geographic constraints. Typical geographic constraints are access to labor, resources such as water and chemicals, and the proper ecological conditions conducive to growing the most productive varieties of coca. Many additional constraints arise from being an illicit business:

- Locating in inaccessible zones beyond the reach of the police or government armed forces.
- Distrusting other business associates and foregoing legal remedies.
- Keeping in touch with underground information about markets for supplies and coca products.
- Paying high fees and bribes for security.

We will show in this chapter that these constraints *inherently restrict transportation, causing cultivation to tightly concentrate into dense zones*. A casual glance at Figure I-2 shows how concentrated illicit coca cultivation was in 1997. Moreover, the inaccessibility of these producing regions and the security threats to any form of transportation virtually require traffickers to fly the refined coca products out of the growing regions.[1] Because air transport has no effective substitute, it becomes an inherent vulnerability – a choke point – of the cocaine business.

This chapter will also show that counterdrug operations in Peru have caused further concentration of cultivation in Colombia. This degree of concentration should make air transport within Colombia an even more lucrative interdiction target, thus, increasing the potential for delivering a large and possibly decisive blow against the profitability of the principal agricultural sector of the cocaine industry.

Because these and other factors inherently force the coca business to concentrate, we will show this refutes the expansion assumption.

---

1 Although overland and river routes are available, they involve many more risks, wages, long delays, hence, a much higher cost than air transport.

A. COCA PLANTS AND COCA PRODUCTIVITY

The unique history and agronomy of the coca plant strongly contributes to the concentration of cultivation into inaccessible areas. Coca originated in the Andes of South America and was revered by pre-Inca peoples as early as 500 BC. Coca leaf was used in religious ceremonies and is still used to combat the debilitating effects of high altitudes. Cocaine alkaloid was first isolated and purified in the mid-1800's. It came into common use by the late 1800's, but by the early 1900's, people recognized its harmful effects and began regulating it as a drug. While coca flavorings are still used in soft drinks, the cocaine alkaloids are removed and discarded. Coca has been cultivated in numerous countries in the orient, Central America, the Caribbean, and even Florida. For various reasons, however, by the mid-1900's coca cultivation had been virtually abandoned in all of these areas except South America (Ref. 31).

1. Coca Plant Varieties

Although there are over 200 varieties of the coca plant, only four produce enough alkaloid content in their leaves to be cultivated for cocaine production. Among these, Erythroxylum Coca variety Coca, known as upland coca, is by far the most productive and most widely grown, but as the name implies, is limited to higher altitude regions – from 200 to 2,000 meters along the eastern margins of the Andes. E. Coca var. Ipadu, known as lowland or Amazonian coca, will grow below 200 meters in many areas of the Amazon basin; however, it is only one-half to one-fifth as productive as upland coca. The other two cultivated varieties are E. novogranatense var. novogranatense, also known as "Colombian coca," and E. novogranatense var. truxillense, also known as "Trujillo coca." Trujillo coca is grown in Peru as a flavoring agent for Coca Cola®, and in Ecuador and Colombia for chewing. Both varieties of E. novogranatense also produce high levels of a related alkaloid, cinnamoylcocaine, that presents significant difficulties for extracting cocaine for illicit drug trade.

Licit markets for coca in Peru and Bolivia precludes enforcement of a total ban on coca throughout the Andean countries. Because of the illicit market, the Peruvian and Bolivian governments tightly control the licit coca crops and production. Although there is always some leakage from licit production into the illicit market, local law enforcement could hold this to very moderate amounts if the overall cocaine business were diminished to scattered freelance operators.

2. Coca Productivity Factors and Agronomy

Four factors contribute to potential productive capacity of a cocaine-producing region: net coca cultivation, leaf yield, leaf alkaloid content, and processing efficiencies. All but the last of these depend upon coca agronomy.

a. Net Cultivation

Net cultivation is simply the total farm area of mature and harvested coca measured in hectares.[2] In the 1990's, the Crime and Narcotics Center (CNC) of the Central Intelligence Agency began conducting annual satellite surveys of farms in the growing regions. Although fruit trees and other crops are often dispersed throughout coca fields, the equatorial satellite perspective enables accurate annual counts of actual coca cultivation throughout the survey areas. Relatively high sampling rates up to 17 percent and periodic on-the-ground examination of fields ensures the consistency and accuracy of these surveys. Although there is some controversy about whether all significant patches of cultivation have been detected and surveyed, this is a marginal uncertainty and has little effect on the analyses and results of this report. Since the CNC continually collects reports of new growing areas, these cannot become very large or dense before they are surveyed and assessed.

Because coca matures slowly it requires a great deal of front-end investment for poor farmers and also complicates the estimation of coca harvest from overhead surveys of viable plants. Upland coca is grown from seedlings and takes 2 years to become productive and leaf yields peak a few years later. Although the plants can live up to 30 years, productivity begins to fall after 8 years. Lowland coca is grown from cuttings and matures to produce a harvest within a year. It takes a couple years to reach full productivity. Also, up to 15 percent of the plants die each year in Peru and may or may not be replaced immediately; therefore, surveys must recognize and correct for the amount of dead coca within fields. The DEA conducted Operation BREAKTHROUGH (Ref. 17; Ref. 32) in both Bolivia and Peru to measure the harvest yields from typical farms and assess the conversion efficiency into cocaine.

b. Leaf Yield

Leaf yield is the amount of air-dried leaf produced per hectare per year. Typically, farmers harvest all of the leaves three, four, or even five times a year

---

2 A hectare is 1/100th of a square kilometer and about 2.471 acres.

depending on the plant productivity and local practices. Ultimately, the annual leaf yields depend upon many factors – the variety of coca being grown, age and vigor of the crop, crop management practices, the fertility and water-holding capacity of the soil, and the weather.

c. Leaf Alkaloid Content

Leaf alkaloid content depends primarily on the variety of coca planted. Upland coca is the principal variety cultivated in Peru and Bolivia. Colombian coca and some Trujillo coca are cultivated in the western and northern regions of Colombia. Until the recent planting boom in Western Colombia, the bulk of the Colombian coca crop was lowland coca from the Guaviare. The DEA used the analytically more reliable oven-dried leaf of the upland variety to obtain its yield of 0.71 percent alkaloid. However, the typical coca growers in Peru and Bolivia use air-dried leaf that has more water and a lower alkaloid content of 0.59 percent by weight. Recent surveys show that the leaves of the "lowland" variety yield about 0.149 percent alkaloid for wet leaf, and the "Colombian" variety yields about 0.136 percent for wet leaf (Ref. 5, Colombia, 1999).

d. Processing Efficiencies

Processing efficiencies have a large impact on overall production according to a joint research paper (Ref. 30).[3] Base lab efficiencies from Operation BREAKTHROUGH showed that Bolivian and Peruvian "chemists" were able to extract less than 45 percent of the cocaine alkaloid using their water-pit, leaf-stomping technique. The CNC joint research indicates that Colombian "chemists" use larger scale and different techniques for base production and probably achieve higher 70 percent efficiency (Ref. 5, Colombia, 1999). For cocaine laboratory processing, Operation BREAKTHROUGH showed that typical "chemists" operating typical laboratories with adequate chemicals could achieve a 1:1 conversion efficiency going from coca base to cocaine. This is possible because cocaine is slightly heavier than the base compounds. However, cocaine laboratory efficiency is also measured by its ability to obtain the proper chemicals, recycle and conserve these, and respond to surge demands. Colombian labs can do this on a large scale, Peruvian labs are smaller but efficient, while most Bolivian labs currently produce an inferior product because they are starved for the proper chemicals.

---

[3] This CNC paper assumed Colombia's western regions were growing upland coca. Subsequently, they learned it was Colombian coca (Ref. 5, Colombia, 1999).

Since the Peruvian and Bolivian Governments have gained much more control and access to growing regions and farmers are much less hostile than in Colombia, Operation BREAKTHROUGH provided substantial information about coca processing in Peru and Bolivia. Recent updates of DEA research in Colombia reported through CNC (Ref. 5, Colombia, 1999) have been able to estimate Colombian productivity of cocaine per hectare. Taking into account the size and number of harvests, alkaloid content of the leaf, and processing efficiency, the Guaviare and eastern Caqueta regions get 4.9 metric tons of cocaine for every 1,000 hectares of cultivation. The Putumayo, western Caqueta, and northern regions get between 3.7 and 4.0 metric tons per 1,000 hectares. By comparison, Peru gets between 4.5 and 4.7 metric tons of cocaine per 1,000 hectares. Bolivian productivity has steadily fallen as their processing efficiencies declined and the Chapare region collapsed; their corresponding estimated rates are 6.00 in 1995, 5.8 in 1997, and 4.1 in 1996.

B. CONCENTRATION OR DISPERSION

It is important to understand the balance of forces between geographical concentration and dispersion because these shape the interdiction zones. We believe that concentration is essential to market efficiency and forced dispersion also causes a decline in product quality and enhances options for government control and alternative development. Geographic concentration and dependence on air transport create a lucrative interdiction target; therefore, understanding these influences is key to assessing interdiction options and trafficker responses.

1. Forces Toward Concentration

Many items have to be transported to support coca base production – agricultural chemicals to farms, leaf and chemicals to processing pits near a water supply, coca base to cocaine labs, as well as all of the supplies for local day-to-day living. In the undeveloped producing areas, transportation is difficult. Another force for concentration is the need for farmers and producers to find buyers and know enough about the market to believe they are getting fair market prices.

a. Need for Access to Supplies, Labor, and a Market

It typically takes over 100 kilograms of mostly common chemicals and much more water to process one kilogram of coca base (Ref. 17). Agricultural practices vary widely, but productivity depends upon use of insecticides, herbicides, and fertilizers.

Most farms grow as much or more food as cocaine, which increases this need for chemicals.

Hiring labor to transport leaf and chemicals to processing pits near rivers, hiring chemists to assist making the base, and arranging buyers all require market awareness and social contact. Security awareness about police actions benefits from frequent word of mouth contact, and protection of the crop benefits from living near the cultivated plot.

b. Difficulties of Land Transportation

Because coca cultivation for cocaine is illicit, growing areas were selected to be outside government control, and hence without a developed infrastructure of roads. Since most of these growing areas were only sparsely populated before the cocaine epidemic, even the coca producers were unfamiliar with these rugged areas of Andean mountain valleys or upper Amazon jungle.

Alternative development programs do enhance the road system as well as schools and medical clinics. However, improved accessibility to in these regions comes as part of a bargain with the government to increase legal authority in the area. It is ironic that alternative development tends to stabilize a population in or near growing regions, yet most of that population originally migrated to the region solely to grow illicit coca. While governments may wish to develop their rugged interiors, alternative development away from the growing areas would reduce the temptation of illicit coca cultivation on the side. The UNODCCP in Vienna, Austria said that donor countries are willing to support alternative development in growing areas, but not "development" away from growing areas, which is looked upon as creating competition with established donor interests.

c. Difficulties of River Transportation

Even a cursory examination of the maps of the growing areas shows that the rivers flow toward the Amazon and away from the closer markets west over the Andes Mountains. A closer look shows that the growing regions are laced by small tributaries or are clustered along major rivers in mountain valleys. This river network supports a large portion of local transportation and the traffic in bulk chemicals from larger towns or access points along the major rivers. However, transporting a valuable commodity such as coca base or refined cocaine by river slows transactions, increases the risk of informants, and invites opportunistic piracy or interdiction along the course of the

journey. Hired security forces and bribes to cover a longer duration transport increase costs.

Nevertheless, some coca base or cocaine goes overland or by river. There have been interdictions near Iquitos before the Amazon leaves Peru. Higher coca base prices at various points where rivers leave Peru attest to the cost of getting there from growing regions. Patrolling the rivers in Peru is a developing phase of interdiction that is difficult but should evolve with experience.

d. Need for Air Transportation

Local cultivation and base processing activities can cluster to reduce the ground transportation burdens, but longer distance transport to efficient cocaine laboratories and to eventual market overseas strongly favors air transport. Alternatives ground modes are possible, but we shall see in the next chapter that traffickers are willing to pay very high fees to sustain the air mode.

2. Forces toward Dispersion

Several factors act to disperse cultivation from the most highly concentrated growing areas such as the Upper Huallaga Valley (UHV) in Peru.

a. The Fungus Fusarium Oxysporum

A host-specific variety of the fungus fusarium oxysporum attacks coca causing it to die within 3 to 9 months. Fusarium oxysporum spreads as mycelium (the threadlike growth of the fungus), or as spores in running water, on farm equipment, on transplants of infected coca, and even on the shoes of coca growers.

Fursarium oxysporum is endemic in Peru, but epidemic outbreaks are rare. In the most recent outbreak, fusarium oxysporum was first noticed in the town of Uchiza in the UHV. By June 1991, the fungus had contaminated 1,000 hectares in Uchiza and 5,000 hectares in the UHV (Ref. 33). Coca growers moved north to the central Huallaga Valley and east to Aguaytia because of substantially reduced leaf yields and lower prices paid for contaminated coca. Decreases in cultivation in 1991 and 1993 coincided with fungus outbreaks reflecting crop abandonment and replanting in other areas.

b. Terrorism and Extortion

The Sendero Lumioso (SL) or "Shining Path" Maoist guerrilla insurgency extracted extortion payments from farmers and landing fees from Colombian traffickers.

They also contributed to the violence of the concentrated UHV growing areas. Although, the SL "negotiated" higher prices from the Colombian traffickers, many producers dispersed to other areas to avoid the most intense violence.

c. Government Counterdrug Operations

In September 1989, the Peruvian National Police (PNP) supported by the USG opened the Santa Lucia Base in the UHV. This base enabled Peruvian forces to attack labs and allowed DEA Operations SNOWCAP and CORAH to resume gathering intelligence and market data. When the airstrip opened in January 1990, the former traffic of 50 to 60 planes in July 1989 dropped to 5 in February 1990 (Ref. 34, p. 143). These activities forced traffickers to fly from more remote airstrips and dispersed the market areas into the central and lower Huallaga and into Aguaytea and Pachitea. Nevertheless, these regions generated their own concentrated centers of activity, and the pattern of concentration repeated itself elsewhere.

C. THE CONCENTRATION OF COCA CULTIVATION

The following three analyses show that local transportation constraints cause concentration, that coca cultivation is in fact remarkably concentrated within its ecological range, and that after the collapse of the Peruvian coca market, concentrated regions increased faster – or declined less – than more dispersed ones. The first analysis demonstrates that coca cultivation in the Apurimac Valley follows the classical economic geographic theory in which transportation accessibility dictates population distribution. The second analysis demonstrates that coca cultivation in all regions is remarkably concentrated. The third analysis compares regions by their degree of concentration and rates of growth or decline to reveal, what we all know, that cultivation is dramatically shifting to Colombia, but also what is less well known, that concentrated regions do better in all countries. Together, these analyses show that concentration is an inherent feature of illicit coca cultivation and that the reasons we described already appear to be creating ever more lucrative targets for air surveillance and interdiction.

1. Apurimac: A Case Study of Transportation Constraints

Economic geography theory argues that an economic activity, which is constrained by transportation effort, will form an exponential mathematical distribution relative to centers of trade (Ref. 35, pp. 311-14). This result is very general, it is derived from known patterns of travel among destinations. "Opportunity models" of travel

patterns explain how this could apply to Peru's growing regions (Ref. 4, pp. 537-43). This well-established empirical model predicts that trip length falls exponentially in proportion to the number of opportunities the traveler passes to accomplish their economic ends such as employment or purchasing an item. In growing regions, the "opportunities" are locations for coca farms as one travels away from the nearest river – an essential source of water and access to bulk transport. Our analysis of the distribution of coca cultivation in Peru's Apurimac Valley region reveals this exponential distribution signature.

On the overall map of coca cultivation regions, Figure I-2, the Apurimac Valley is just west of the licit cultivation area Cuzco in southern Peru. The Apurimac River drains into the Ene River, which flows out of the cultivation areas.

Until recently, the Apurimac Valley region was too dangerous to enter, but with the collapse of the coca market, researchers from alternative development programs were able to map the Valley's agriculture in detail. The Cuerpo de Asistencia para el Desarrollo Alternativo (CADA) provided a map of the full 10 x 100 kilometers of cultivation region on a scale of better than 1 centimeter = 1 kilometer. The map shows 18,631 ha of licit crops, 13 towns, 7 tributaries, and clearly indicates 10 airfields. There are 8,835 ha of illicit coca in production, 5,487 ha abandoned but somewhat recoverable, and 10,265 ha of coca fields irrecoverably returned to a natural state. Typically, untended coca fields become overgrown with weeds in 6 months, competing plants cover the coca within a year, but a few plants may survive in the wild for much longer.

a. River and Air Transport

Most of the illicit cultivation is concentrated along 100 kilometers of the river, and the CADA map details a 10 kilometers wide swath along this stretch of river. For analysis, we subdivided the 100 kilometers into ten bands of 10 kilometers each transecting the river. Figure II-1 shows the number of hectares of cultivation in each of the ten bands as well as the approximate locations of towns and airfields.[4] Note that the airfields are down river, to the right on Figure II-1, from the bulk of the growing areas.

Clearly, river and air transportation dominate longer distance transport. Thus, rivers are the destination for overland transportation, the most burdensome constraint. A joint effort between the Peruvian and U.S. Governments is building a base and airfield in

---

4 The CADA maps show urban areas in black, and many such areas exhibit long narrow bands on adjacent land or in semi-isolated zones along the river. We interpreted these bands as airfields.

Palmapampa, a town in the center of the cultivation area between 30 and 40 kilometers in Figure II-1. This should greatly enhance interdiction opportunities and further limit trafficker access to the valley.

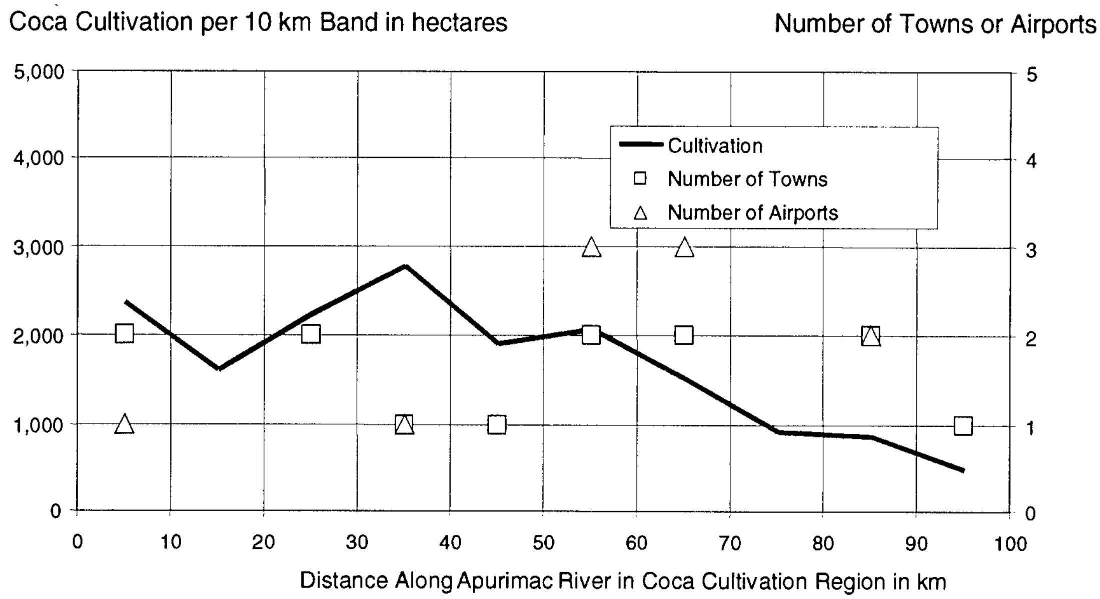


Figure II-1. Cultivation and Infrastructure Along the Coca Region of the Apurimac River Valley, Peru, 1997

b. Overland Transport

Now we analyze the distribution of cultivation in terms of distance from the nearest river, the Apurimac or its tributaries. If this turns out to be exponential, it indicates that land transportation is the principal constraint dictating the distribution of coca farming activity.

We counted the area of cultivation in several zones at different distances from the Apurimac and its tributaries and adjusted these zones by a few percent for those portions not covered by the mapped area. Table II-1 shows the accumulated number of hectares of cultivation by distance from both sides of the river, and for the sum of both sides.

The data points in Figure II-2 show the cumulative number of farms further than a given distance from the river. Figure II-2 also verifies the exponential fit to these data.[5]

---

[5] We fit an exponential to these grouped data, and extrapolated the distribution beyond 4 kilometers, which is beyond the mapped zones. We also excluded the cultivation within 0.5 kilometers of the rivers because low security and environmental variability bias these data downward. The chi square probability for the overall fit was 0.17, where 0.5 is expected at random, a quite close agreement for this type of analysis.

Visual inspection confirms the quality of the fit, excluding for the zone closest to the river that is depleted due to security considerations.

Table II-1. Coca Cultivation (ha) by Distance Zones from a River in the Apurimac Valley

Distance from a River kilometers	South West Shore		North East Shore		All Apurimac	
	Actual	Fit	Actual	Fit	Actual	Fit
4 to all	N/A	1,211	N/A	1,277	N/A	2,528
2 to 4	1,648	1,595	1,583	1,681	3,231	3,257
1 to 2	1,329	1,465	1,695	1,544	3,024	2,967
0.5 to 1	1,065	998	914	1,052	1,979	2,013
0.0 to 0.5	864	1,231	736	1,297	1,600	2,476
Fitted Total	N/A	6,500	N/A	6,850	N/A	13,240
Average Distance		2.38 km		2.38 km		2.42

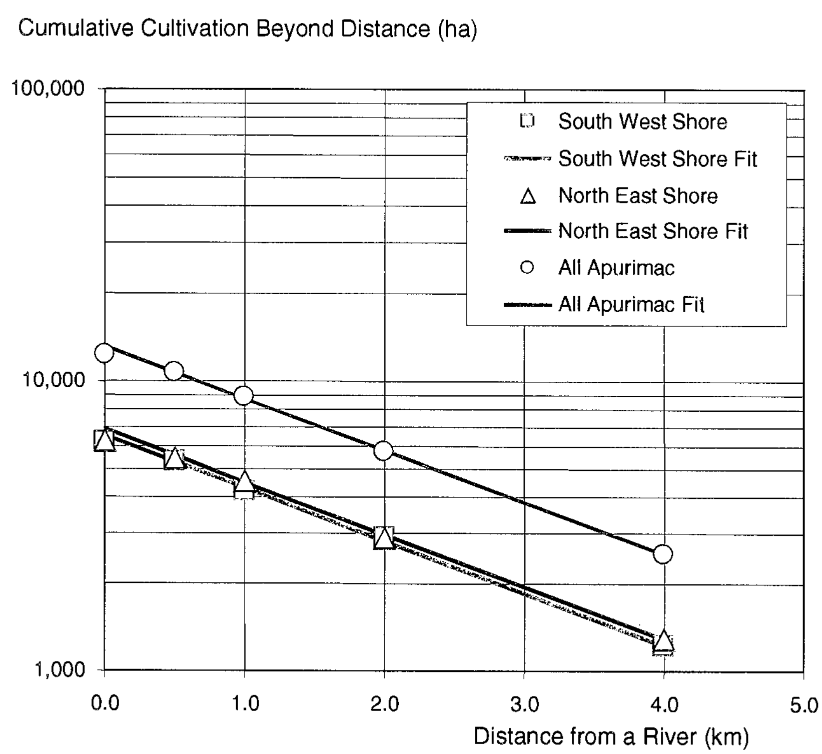


Figure II-2. Exponential Decline in Cultivation with Distance from a River

Thus, the population falls off very sharply with distance from a river – an average distance of only 2.4 kilometers, and slightly clusters around major towns along 100 kilometers of river. This short average distance of overland travel reveals the extreme difficulty encountered. The nearly 100 kilometer spread along the river indicates the relative importance of river transport for access to markets and bulky products. Finally, the proliferation of airfields shows the dependence on air transport for long-distance travel and high-value trade.

2. Analysis of Cultivation Density Patterns

The Apurimac Valley analysis illustrated the dense distribution of cultivation caused by local transportation constraints. We now ask, how concentrated is coca cultivation throughout the Andean growing regions? We compare the aggregate coca cultivation within central zones, entire regions, cultivatable land, and total national territory.

a. Distribution of Cultivation

The 1997 distribution of cultivation is mid-way between the pre-1995 condition before the market collapse and 1999, at which time the Peruvian coca market appears to be stabilizing at a much lower level. Figure II-3 is a 1997 CNC contour map of the growing regions in Peru, and shows the zones of various cultivation densities, 0 to 1, 1 to 4, 4 to 8, and more than 8 hectares per square kilometer. We measured the areas of those zones for Colombia and Bolivia as well as Peru and summarized them in Table II-2.

Table II-2 does not include all cultivation because there were 7,000 ha of coca in "other" scattered low-density areas of Peru, and the Apolo region of Bolivia is too small and sparse to contribute to our analysis. The row labeled "All Huallaga" consolidates its five component regions, some with no high-density zones. The last column of Table II-2 lists the CNC's estimate of mature coca cultivation for each region. Since Peru was in steep decline during 1997, it is unlikely that there was much newly planted, immature coca not included in the cultivation totals.

Figure II-3. Contour Map of Peru's Coca Cultivation Density in 1997

Table II-2. 1997 Coca Growing Regions by Area and Cultivation

Region	Areas of Density Zones in square kilometers				Cultivation
	0 to all	1 to all	4 to all	8 to all	hectares
Lower Huallaga	7,260	550	0	0	2,800
Central Huallaga	6,310	285	0	0	2,500
Upper Huallaga	13,900	5,730	1,355	440	25,000
Aguaytia	7,800	1,250	630	320	8,400
Pachitea	8,710	0	0	0	2,200
All Huallaga	43,980	7,815	1,985	760	40,900
Apurimac	5,240	1,520	1,170	350	12,600
Cuzco	7,140	1,630	540	50	8,300
All Peru	56,360	10,965	3,695	1,160	61,800
Yungas	4,513	1,622	862	318	14,000
Chapare	8,803	6,581	3,302	798	31,500
All Bolivia	14,399	8,203	4,165	1,116	45,800
Caqueta	15,679	10,567	2,246	292	31,500
Putumayo	4,722	3,903	1,975	798	19,000
Guaviare	42,572	11,113	1,528	168	29,000
All Colombia	62,973	25,583	5,749	1,258	79,500
All Andean	177,712	52,566	15,594	4,294	187,100

Figure II-4 plots the density versus area values from Table II-2 for each major region. All regions show a sharp rise to a concentrated core of density greater than 8 hectares per square kilometers. Only three of the eight regions do not have significant fringe zones – Putumayo in Colombia and Chapare and Yungas in Bolivia.

Because many of the density profiles cross one another, it is unlikely that one mathematical model of the profile can be fit to all of the regions. This reflects the different nature of these regions – some are river valleys, some are on the rising fringes of the Andes, and one is spread out in a lower area of the Amazon. Therefore, we adopted a simpler method of characterizing concentration of cultivation.[6]

---

6 To estimate concentration within regions along curves in Figure II-4, we extrapolated from the highest density zone boundaries, 4 and 8, to the peak density in two ways, linearly and exponentially. These extrapolations can easily be integrated to estimate the average density of cultivation within the zone of density greater than 4 hectares per square kilometer. Since both the linear and exponential extrapolations gave very similar results for all regions, we chose the simpler linear extrapolation for our estimate of central density. From this linear extrapolation, the average density within zones of density 8 or more was 10 hectares per square kilometer, and the average density of zones between densities of 4 and 8 was 6 hectares per square kilometer. With these average densities, it was easy to estimate the cultivation within the zones of density 4 or more.

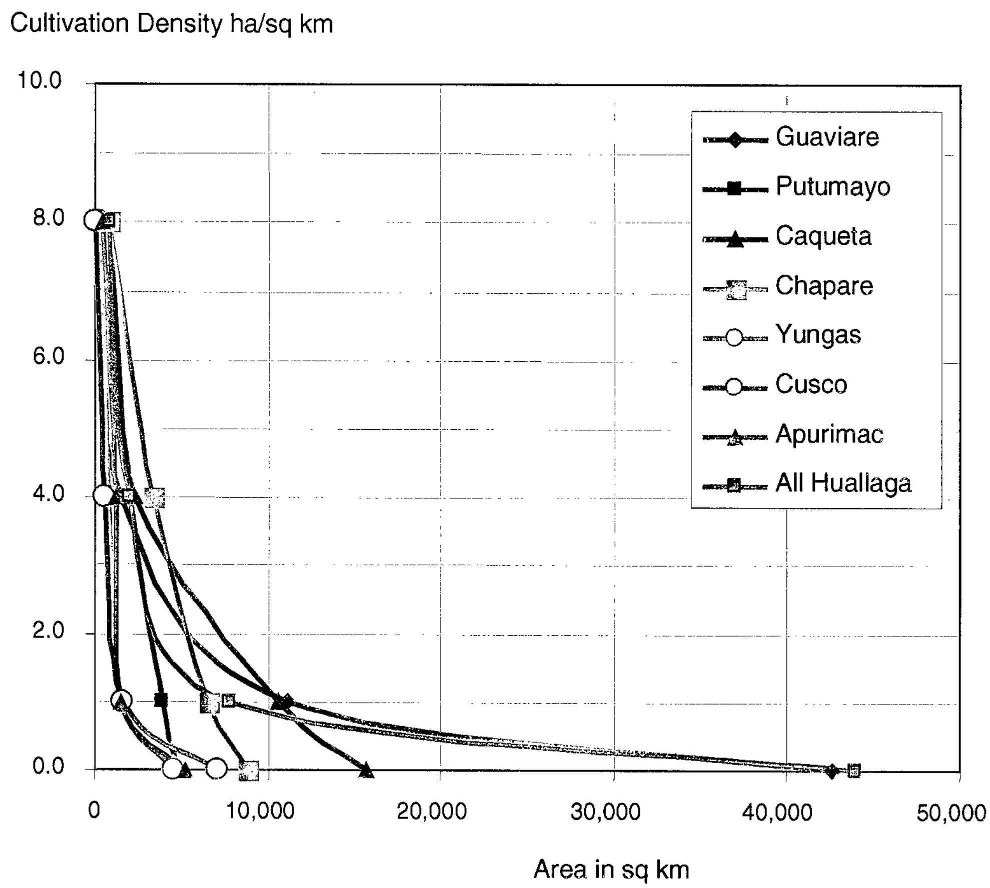


Figure II-4. Density Profiles of Major Growing Regions

b. The Degree of Concentration of Coca Cultivation

Table II-3 summarizes the cultivation, areas in square kilometers, and densities for each region and its central zone of density greater than 4 hectares per square kilometers. It also gives the area and percent of cultivation within each region's central zone. The key findings about these dense core zones of 4 hectares per square kilometer or more are the following:

Table II-3. Cultivation Concentration within Dense Central Zones

Region	Total Region			Central Cultivation			Central Areas	
1997 Data	hectares	sq km	ha/sq km	hectares	Percent	ha/sq km	sq km	Percent
Lower Huallaga	2,800	7,260	0.39	0	0.0	0.000	0	0.0
Central Huallaga	2,500	6,310	0.40	0	0.0	0.000	0	0.0
Upper Huallaga	25,000	13,900	1.80	9,890	39.6	7.299	1,355	9.7
Aguaytia	8,400	7,800	1.08	5,060	60.2	8.032	630	8.1
Pachitea	2,200	8,710	0.25	0	0.0	0.000	0	0.0
All Huallaga	40,900	43,980	0.93	14,950	36.6	7.531	1,985	4.5
Apurimac	12,600	5,240	2.40	8,420	66.8	7.197	1,170	22.3
Cusco	8,300	7,140	1.16	3,440	41.4	6.370	540	7.6
All Peru	61,800	56,360	1.10	26,810	43.4	7.256	3,695	6.6
Yungas	14,000	4,513	3.10	6,447	46.0	7.475	862	19.1
Chapare	31,500	8,803	3.58	23,005	73.0	6.966	3,302	37.5
All Bolivia	45,800	14,399	3.18	29,452	64.3	7.072	4,165	28.9
Caqueta	31,500	15,679	2.01	14,644	46.5	6.520	2,246	14.3
Putumayo	19,000	4,722	4.02	15,042	79.2	7.616	1,975	41.8
Guaviare	29,000	42,572	0.68	9,840	33.9	6.440	1,528	3.6
All Colombia	79,500	62,973	1.26	39,526	49.7	6.875	5,749	9.1
All Andean	187,100	177,712	1.05	110,738	59.2	7.101	15,594	8.8

Note: Central areas and cultivation refer to zones of density > 4 hectares per square kilometer.

- For all Andean growing regions together, 59 percent of all cultivation is compressed into only 9 percent of the cultivated areas.
- For Peru and Colombia, over 40 percent of the cultivation is compressed into less than 10 percent of their cultivated areas, while Bolivia is more uniformly dense and compact with 64 percent of cultivation on 29 percent of the cultivated land.
- Some regions are quite diffuse with small dense cores, for example, all of the Huallaga Valley in Peru with only 36 percent of cultivation within the central zone on only 4.5 percent of the land, Aguaytia with 60 percent of cultivation on 8 percent of the land, and the Guaviare in Colombia with only 34 percent of cultivation on 3.6 percent of the land.
- Some regions are quite dense and compact, for example, Apurimac with 67 percent of cultivation on 22 percent of the land, Chapare with 73 percent of cultivation on 38 percent of the land, and Putumayo with 79 percent of cultivation covering 42 percent of the land.
- While the average central cultivation density ranges only from 6.4 to 8 hectares per square kilometer, the total regional average densities range widely from 0.68 to 4.0 hectares per square kilometer.

c. Summary of Concentrations within Countries and Ecological Ranges

To summarize and underscore the degree of concentration of coca cultivation areas, we also estimated for each country the area of land suited for coca cultivation and the area of national territory. For simplicity, the potential area of cultivation includes all regions similar to those of current cultivation, regional totals do not distinguish between upland and lowland coca in Colombia, and licit cultivation includes all of Cuzco and Yungas.

Table II-4 shows the extreme degree of concentration of coca cultivation in 1997 measured in square kilometers of land area. Figure II-4a shows the degree of concentration by national territory while Figure II-4b compares the areas of coca growing regions and central zones with the area of land potentially suited to coca growing. Looking at Figure IV-4b, it is hard to believe that the dense central zones contain nearly 60 percent of all cultivation.

Table II-4. Degree of Concentration of Cultivation within Producer Countries

	Areas in Square Kilometers				
Country	**All**	**Coca Ecology**	**Any Cultivation**	**Licit Cultivation**	**Central Cultivation**
Colombia	1,138,910	140,000	63,000	0	5,750
Peru	1,285,220	150,000	56,000	7,140	3,700
Bolivia	1,098,580	100,000	14,400	4,513	4,170

Sources:

Total area of Peru: Annmarie Muth, editor, "Statistical Abstract of the World," third edition, Gale Publishing, 1997.

Note that Colombia includes only Guaviare, Caqueta, and Putumayo. The San Lucas and Norte de Santander constitute only small, newly incorporated additional areas. These areas have approximately the same average density as those included.

Licit production is about one-half of the Cuzco Region of Peru in 1997, and about 9/10th of the Yungas Region of Bolivia in 1997. However, we have shown the entire dense areas of Cuzco and Yungas above.

Central cultivation is the area of farm density 4 hectares per square kilometer or more.

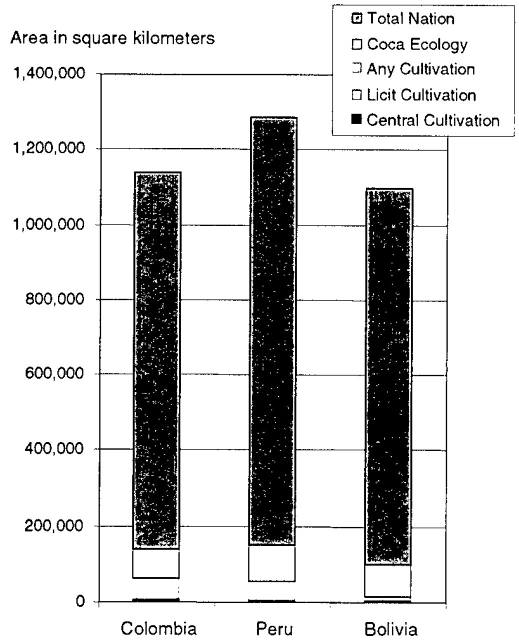


Figure II-4a. Concentration of Coca Cultivation for 1997 – National Territory

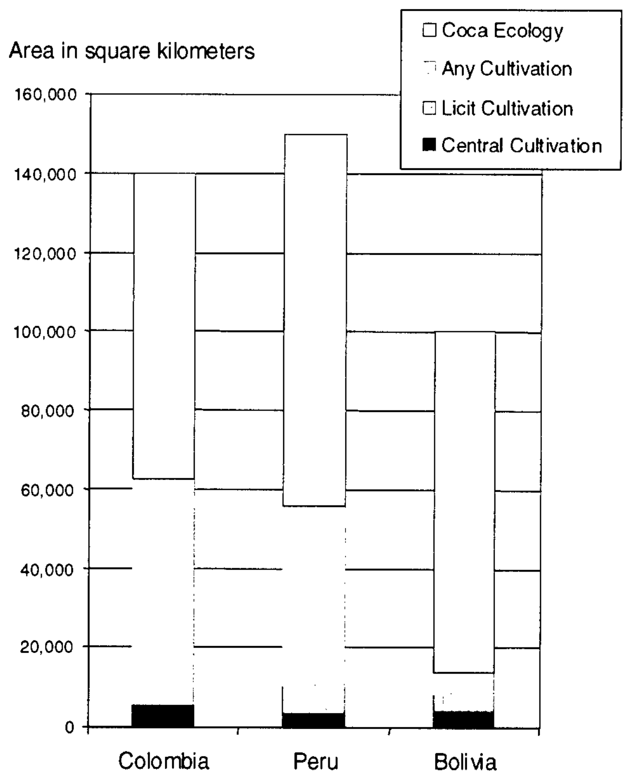


Figure II-4b. Concentration of Coca Cultivation for 1997 – Coca Ecology

Since several distinct and distributed locations make up a region's central zone, the interdictors' surveillance, detection, and monitoring tasks are somewhat more spread out than just the combined area of central zones. At the other extreme, the surveillance and D&M task is less spread out than the diffuse fringes of the regions. Therefore, the D&M task is simplified for compact regions with high overall average density. Now we will take a detailed look at the evolution of average density over recent years.

3. Growth and Decline of Cultivation Regions

Rates of regional growth or decline are another indicator of the importance of concentration to traffickers. We now show that on average the most rapidly growing regions in Colombia and the least rapidly declining regions of Peru and Bolivia are the relatively most dense within their respective countries.

We already know the average regional densities from the baseline year, 1997, and we can obtain the rates of growth or decline by comparing the total cultivation for each region over the transitional period from 1995 to 1998. We checked that the regional boundaries vary by only a few percent over this time interval while cultivation varied much more. Therefore, the 1997 average regional densities – taken mid-way in the transition – are a good overall indicator of regional compactness.

a. The Regional Data

Table II-5 summarizes the regional cultivation in hectares for all of the regions designated by the CNC as well as the total areas for these regions in 1997. We left out the San Lucas and Norte de Santander regions of northeastern Colombia because we do not have data on their growth history – these two small compact pockets totaling 5,600 ha were added to the survey in 1998. Their combined contribution was also subtracted from Colombia's cultivation totals. For the analysis, we will also drop "Other" cultivation from Peru because there was no corresponding area estimate and "Apolo" from Bolivia because the CNC's cultivation sampling errors were much larger on this tiny isolated region. Unlike the concentration analysis of the last section, we disaggregate the "All Huallaga" into individual regions. Finally, there have been recent reports of new growing areas developing in northern and in southeastern Peru. Even if some new cultivation has developed in unsurveyed areas, it could not contribute significantly to this analysis for two reasons. First, to be large enough to have an impact it would have been detected and surveyed. Second, the results rest on an analysis of the bulk of all known coca cultivation, and we have reliable data for these areas.

Table II-5. Regional Growth and Decline from 1995 to 1998

Region	Cultivation in ha				1997 Areas
	1995	1996	1997	1998	Sq. kilometers
LHV	6,500	5,000	2,800	1,000	7,260
CHV	6,500	5,000	2,500	1,100	6,310
UHV	33,700	29,400	25,000	21,000	13,900
Aguaytia	19,600	15,000	8,400	4,800	7,800
Pachitea	7,100	6,200	2,200	1,300	8,710
Apurimac	21,000	16,800	12,600	9,000	5,240
Cusco	10,000	9,000	8,300	7,500	7,140
Other	10,900	8,000	7,000	5,300	N/A
All Peru	115,300	94,400	68,800	51,000	56,360
Yungas	14,000	14,400	14,000	14,200	4,513
Chapare	33,700	33,000	31,500	23,500	8,803
Apolo	900	700	300	300	1,083
All Bolivia	48,600	48,100	45,800	38,000	14,399
Caqueta	15,600	21,600	31,500	39,400	15,679
Putumayo	6,600	7,000	19,000	30,100	4,722
Guaviare	28,700	38,600	29,000	26,700	42,572
All Colombia	50,900	67,200	79,500	96,200	62,973

From these data, we calculated the 1997 average cultivation density for each region in hectares per square kilometers and the ratio of 1998 to 1995 cultivation expressed as a percent. Table II-6 shows these values for every region to be included in the analysis. Visual inspection of Table II-6 shows that the Colombian regions are growing much more rapidly than Peruvian or Bolivian regions of comparable density. Inspection also shows that more dense regions increased relative to less dense. We found that these qualitative observations could be fit by regression analysis to a more precise mathematical model. Readers, who do not wish to go through the mathematical details of fitting this model, can skip the next subsection to see the results of the analysis given in subsection II.C.3.c.

b. Analysis of the Transition from Peru to Colombia

The simplest linear regression model would consist of a term distinguishing Colombia from the other two producer countries, a term relating growth to density, and a constant term. However, we want a model that represents relative decline on a comparable scale to that for relative growth; therefore, we chose to fit to the logarithms of the ratios of cultivation change. We also found that the logarithm of density gave a better fit than density itself, an R^2 of 0.96 versus 0.68; thus, we chose log-density as the

independent variable. The other regression parameters are the scaling constant and the log of the scaling *factor* advantage that Colombia has over the other countries. We also excluded Cuzco in Peru and Yungas in Bolivia from the fit because these licit cultivation regions should not decline in proportion to the illicit cultivation regions. In fact, they did not decline since the fit to the model improved greatly without them, R^2 of 0.96 versus 0.91.

Table II-6. Cultivation Density and Regional Change

Region	1997 Average Density ha/sq km	Percent of 1995 in 1998
LHV	0.386	15.4
CHV	0.396	16.9
UHV	1.799	62.3
Aguaytia	1.077	24.5
Pachitea	0.253	18.3
Apurimac	2.405	42.9
Cusco	1.162	75.0
Yungas	3.102	101.4
Chapare	3.578	69.7
Caqueta	2.009	252.6
Putumayo	4.024	456.1
Guaviare	0.681	93.0

Figure II-5 shows the regional data and our regression model on a log-log plot. Cuzco and Yungas are plotted as symbols without color fill to show that they deviate from the model as expected. For the fitted regions, this model represents these data remarkably well given the very approximate nature of the indicator variables.

A more sophisticated model would take into account the changes in the areas of the cultivation regions from 1995 to 1998 and possibly add other factors. However, it is difficult to improve a model that already explains 96 percent of the variation.

The final model is then:

$$R_g = 0.312 \cdot F_c \cdot D^{0.638}$$

where R_g is the ratio of growth between 1995 and 1998, F_c is the growth factor advantage for Colombian regions, and D is the average regional cultivation density. The fitted parameters and their relatively small uncertainties are:

- Density parameter: 0.637 ±0.093; a 15 percent uncertainty
- Colombian growth factor advantage: $F_c = 4.91$ with a 20 percent uncertainty

Baseline factor: 0.312 with a 10 percent uncertainty.

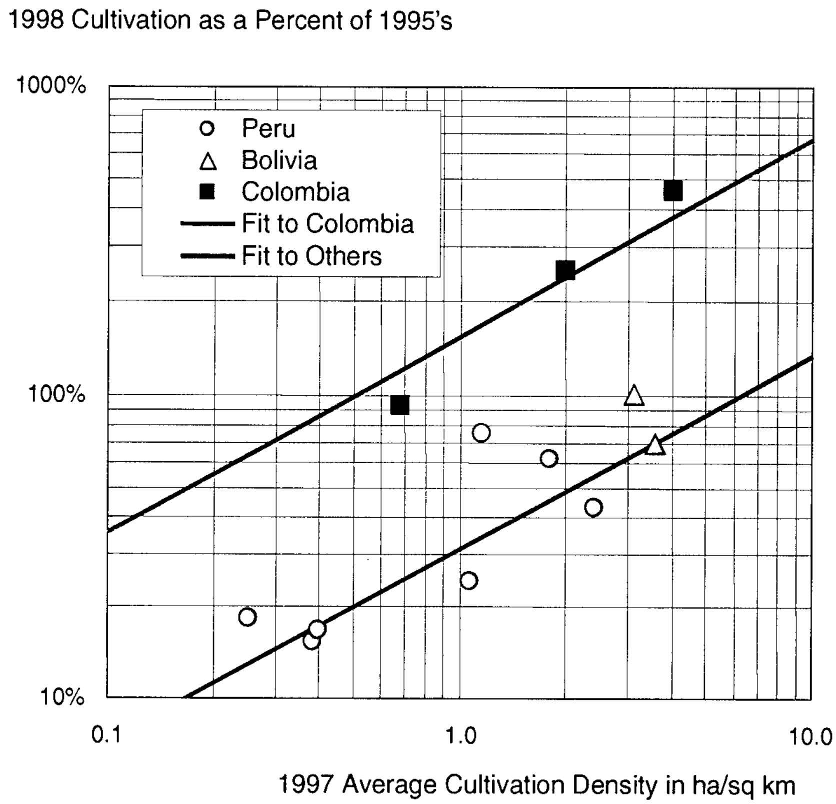


Figure II-5. Relationship between Growth or Decline and Regional Density

Note that with the fitted density parameter, it would take an impossible factor of 12 increase in density to make up for Colombia's growth advantage.

Since the changes from 1995 to 1998 took place over three years, on average the yearly changes would be R_g raised to the $1/3^{rd}$ power. In general, this would be:

$$R_g = 0.678 \cdot F_c^{0.333} \cdot D^{0.213}$$

Because $4.91^{0.333} = 1.695$, Colombian regions increase 70 percent more per year than regions of comparable density in Peru or Bolivia.

For Putumayo with a density of 4.02, the yearly average change would be a ratio of:

$$R_g = 0.678 \cdot (4.91)^{0.333}(4.02)^{0.213} = 1.55,$$

which is a 55 percent increase per year. Actually, Putumayo increased by a factor of 4.56 over 3 years, or 66 percent per year. Figure II-5 shows this discrepancy since the regression line passes slightly under the data point for Putumayo.

c. Increased Concentration of Cultivation and Its Implications

Our model shows that Colombia's growing regions enjoy a extraordinary growth advantage: a 70 percent per year growth advantage over Peru's and Bolivia's regions with comparable density. It also shows that the annual rate of growth, or diminished rate of decline, is greater for the more dense regions. Regions with twice the overall density of other regions have an annual growth advantage of 16 percent. Similarly, regions with ten times the density have an 81 percent growth advantage per year.

In Colombia, the lack of government control and the presence of most of the world's cocaine processing capacity explain its huge growth advantage over Peru and Bolivia. Moreover, one specific region, Putumayo, with the highest growth rate is also the most compact of all regions. This growth exemplifies the near absolute protection from government intervention provided by Marxist revolutionaries, the FARC.

The licit growing regions of Cuzco in Peru and Yungas in Bolivia enhance the credibility of our model. One would expect that licit growing regions would decline much less than illicit ones during periods of strong decline for illicit cultivation. This is what has happened for Cuzco and Yungas because they have low rates of decline relative to illicit regions of similar density and location.

A simple interpretation of our model is that coca production flourishes in more compact regions where there is little or no government control over either the region or its access to world markets. Deterring most of the traffic over the air bridge from Peru to Colombia in 1995 caused the growing areas of Peru to decline sharply while the more protected Putumayo and Caqueta regions of Colombia grew rapidly to replace lost source of supply.

Now let us review some recent changes. As of early 1999, the dense regions of Bolivia had continued to decline because producers cannot effectively supply chemicals into the Chapare or the Yungas. Bolivian political attitudes have shifted against the illicit

coca farmers, and further interdiction of chemicals and alternative development are enhanced by more popular support for the government. Between 1996 and 1999, outlying growing regions in Peru declined rapidly without easy access to market and increasing government control since the Shining Path lost power and what little popular support they ever had. Apurimac is somewhat more concentrated than the Upper Huallaga Valley and Aguaytia regions, but Apurimac has begun an effective alternative development program associated with the CADA survey.[7] These alternative development programs found that farmers will accept up to 60 percent reduction in annual revenues to avoid the violence and risk associated with illicit coca production.

Current trends increase regional concentration throughout the illicit coca growing regions of the Andes and concentrate the industry even more into Colombia. This should actually improve the operational conditions for effective air interdiction. Such concentration creates a much more lucrative air interdiction target because this compact airspace can be more efficiently monitored than the highly dispersed regions of only 5 years ago. From this viewpoint the concentration of the illicit coca industry *and of interdiction forces* present opportunities for decisive engagements that might eliminate the profitability at the core of the cocaine industry.

D. EVIDENCE THAT REFUTES THE EXPANSION ASSUMPTION

Although unchallenged regions such as the Putumayo can rapidly expand cultivation, they cannot readily disperse total cultivation over large areas. Several factors inherent to illicit coca cultivation all conspire to keep growing areas compact: the agronomy of the coca plant, lack of transportation in the growing areas, and threats of piracy from competing trafficker organizations. Historically, it has only been when producers are challenged by fungus epidemics or government intervention, *and coca base prices have been high*, that new regions arise in neighboring areas. However, these new regions have proven to be much more vulnerable to market interruption and price downturns, and they are now declining most rapidly relative to other areas. Overall, recent patterns of growth and decline throughout the Andean producing regions show that the shift from Peru to Colombia greatly *increased concentration*. Thus, rather than easily expanding cultivation, traffickers have barely managed to replace lost cultivation while

---

7 Adding another parameter to our model to represent alternative development programs would reduce much of the discrepancy between the Apurimac and the Upper Huallaga Valley revealed in Figure II-6. (See also footnote 10 in Summary.)

creating more concentrated growing regions, which are potentially more vulnerable to transportation interdiction.

Militarily, compact zones depending on air transport are vulnerable to air interdiction operations. If air interdiction can be successful, traffickers will face the dilemma of challenging the interdiction forces or dispersing to less efficient operations. *Dispersion under low-price conditions probably will not sustain either product quality or profitability for the illicit coca industry.* These considerations refute the commonly held assumption that coca cultivation can freely expand to offset virtually any level of interdiction. Fundamentally, the issue is whether air interdiction operations can capitalize on the greater concentration caused by the pressures from previous operations.

There is an urgency to act and exploit the current compact conditions, which appear to be unique to coca. The three factors of net cultivation, leaf yields, and alkaloid content all depend upon the plant agronomy and pose more severe geographical limitations for coca, unlike heroin poppies, marijuana, and especially synthetic drugs. Therefore, the air transportation choke point may not apply to opium poppy cultivation, and a shift by cocaine traffickers into heroin production and smuggling may not offer a comparable interdiction opportunity. Since producers and traffickers are beginning to distribute heroin through their cocaine distribution networks, we see an urgent need to exploit the air transport vulnerability of the cocaine business to drain illicit revenues that might fund less vulnerable crops if counterdrug pressure were applied slowly over many years.

CHAPTER III

VULNERABILITY OF AIR TRANSPORT

III. VULNERABILITY OF AIR TRANSPORT

The United States has developed the military means and operational understanding of deterrence necessary to establish and sustain air superiority since the advent of air power. In principle, the tools of air superiority can be tailored to police the skies of the coca producing countries. Over Peru, it took a progression of air interdiction operations to learn how to engage air traffickers and to develop an effective working relationship with the Peruvian Air Force (FAP). While the FAP actually interdicted the traffickers flights, the U.S. Government (USG) provided intelligence support, ground-based radars (GBRs), flew airborne radar sorties over coca growing areas, and monitored traffickers as FAP fighter aircraft flew to intercept the traffickers. We therefore begin this chapter by defining a major interdiction operation.

This combined interdiction force also had to learn how to measure the effectiveness of their operations after trafficking appears to decline. Should we continue? Is the job done? Have they found other means of getting around us? These are all questions that need to be answered with objective verifiable information. These questions are examples of the "interdictor's dilemma," and we will explain how they were resolved. Key to resolving the interdictor's dilemma is measuring the impact of interdiction operations on coca markets. Primarily, we rely on measuring the price of the principal export commodity smuggled by the traffickers, coca base. We also analyze the costs of production for coca base and relate these costs to prices in terms of farmers' decisions to grow more coca, just maintain what they have cultivated, or abandon their fields.

While interdictors were attempting to deter traffickers from flying to Colombia, many insurrections, wars, and other types of interdiction operations as well as economic and political turbulence buffeted coca growing nations of Bolivia, Peru, and Colombia. Each of these events had some impact on the fortunes of the Peru's illicit coca trade. One of the members of this research team spent a 4-month internship in Peru conducting research on all of these topics and their impact on the coca business. The core of this chapter is a condensed summary of his research describing significant interdiction and collateral events during each of the air interdiction operations. His research reveals the confusion of the moment as these events unfolded but, when taken as a whole, it

demonstrates that interdiction of air-bridge traffic was the only consistent and plausible explanation for the collapse of the illicit coca markets in Peru. Today, those in Peru with detailed knowledge of drug trafficking agree that shutting down the air-bridge caused the collapse in the coca Peruvian market and subsequent abandonment of 66 percent of all coca cultivation. The interplay of these events reveals lessons for future interdiction operations.

The bulk of this chapter describes each major operation, its impact on the coca market, and key collateral events. We conclude with observations about factors that contributed to the success of the air interdictions in causing a collapse of the illicit coca business in Peru.

A. MAJOR INTERDICTION OPERATIONS

Nearly every military or police action to achieve a given specific objective with finite assets and duration is called an "operation." Goals for the first few operations of any campaign are to probe and learn what can be done and how it is most effectively done. These probes explore the motivations and vulnerabilities of the opposing units and their operations because *the ultimate purpose is to persuade the opposing organizations to cease their hostile or criminal activity.* Operations focused on attacking vulnerabilities of opposing enterprises expect disproportionate, even catastrophic, decline causing more damage to the opposing enterprises than effort expended or losses to friendly units.

For counterdrug (CD) interdictions, we determine whether a major operation is successful by measuring the damage to the illicit coca business to resolve the interdictor's dilemma. Comparisons of product prices with production and transport costs proved to be the simplest way of assessing whether an operation was damaging the coca business.

1. Definition of a Major Interdiction Operation

According to the Bureau of Justice Statistics (BJS), "interdiction is the prevention of illegal drugs from entering the U.S. from foreign sources or transit countries by intercepting and seizing such contraband" (Ref. 9, p.146). This definition is, unfortunately, misleading because it unnecessarily restricts the options to interception and seizure, which implicitly excludes deterring traffickers from continuing in their business. For example, contrast the BJS definition with the Department of Defense's: "Interdiction – an action to divert, disrupt, delay, or destroy the enemy's surface military potential before it can be used effectively against friendly forces" (Ref. 36). Paraphrasing, "drug interdiction is an action to divert, disrupt, delay, or destroy the flow

of drugs before those drugs can be delivered to consumers and users." This alternative definition embraces any and all effective means, including deterrence. The Department of Defense definition of deterrence is:

> [Deterrence is] the prevention from action by fear of consequences – deterrence is a state of mind brought about by the existence of a credible threat of unacceptable counteraction (Ref. 36).

Effective deterrence, for example, causes the bulk of cocaine not to be transported at all. If it is not transported, it cannot be seized. The largest disruptions or shocks to the delivery of cocaine to the U.S. come from large-scale abandonment of trafficker operating modes and routes. The evidence presented in a 1997 IDA paper (Ref. 6), and from other more recent operations is that the effective major operations cause low rates of trafficker activity and *hence* few seizures because of deterrence. Recognition of the deterrent aspect of interdiction operations is crucial to understanding why such operations can be practical, effective, and sustainable.

We define a "major interdiction operation" as one that engages a vulnerability of the cocaine business on a wide enough scale and reaches full intensity in a short enough time that it has the potential to inflict significant damage to the overall cocaine business, causing a serious shock to the industry. Note that this definition does not explicitly refer to the general level of effort of the USG or its allies in counterdrug operations but, rather, only to the impact on the cocaine business. It focuses on the success of specific actions designed to cause a catastrophic failure and collapse of a key sector of the cocaine industry such as transportation or laboratory processing. According to price indicators in Peru and the U.S., several air interdiction operations in Peru from 1991 to 1996 satisfied this definition by attacking a significant fraction of the total illicit coca business capacity at one of its key steps. Only in the source zone can this be done because only in the source zone are the business steps concentrated enough to be attacked across a significant fraction of the total cocaine business.

This report focuses on interdiction operations attacking the air transportation of coca base from production areas to cocaine HCl processing laboratories. While other successful major interdiction operations have targeted cocaine HCl processing laboratories in Colombia, transport of precursor chemicals into processing areas of Bolivia, and transportation from Colombia to points in the Caribbean or Mexico, this paper comments only briefly on these.

Successful major interdiction operations share a number of characteristics:

- They disrupt a significant portion of the flow of cocaine products by attacking a naturally vulnerable choke point in the business process.
- They must cause significant damage to the illicit coca business by raising prices, interrupting flows, or both.
- They need not require a large force or many military assets. Among the most effective operations are those that can be sustained with little cost or effort on the part of the source zone country and the USG because this sustains deterrence even with reduced force levels.
- The most successful operations intimidate the traffickers to the degree that they abandon the most efficient option in the production and distribution chain, thereby reducing flows, profits, product marketability, or all three. While the operation physically interdicts a few traffickers, it deters the majority from continuing – a not so dramatic event easily overlooked by news media.
- These operations are most noticeable when they happen quickly, over a short time scale, such that a clear and dramatic disruption (shock) is observed in the industry. This may also add to the deterrent effect by inducing traffickers to rethink their risks.

Figure III-1 systematizes the processes of planning, conducting, and evaluating a major interdiction operation. It consists of identifying choke points, devising and refining the means of interdicting those choke points during probing operations, conducting a major interdiction operation against the choke point, measuring the impact to verify the damage to the cocaine business, and promptly starting follow up operations now made possible with a weakened cocaine business. These follow up operations include diminishing insurgency or paramilitary threats and the general level of violence, alternative development projects, and greater monitoring and interdiction of precursor chemicals.

2. The Interdictor's Dilemma

Even a successful interdiction campaign encounters the *interdictor's dilemma*: has the operation deterred trafficker activity or have the smugglers found a way of continuing their activity while avoiding detection? If trafficker activity has not been deterred, has the operation caused disproportionate business activity burdens for traffickers? Put another way, are there unequivocal indicators that the interdiction is significantly damaging the illicit coca market? The interdictor's dilemma arises from

limited information and the tendency to focus on trafficker activity versus the consequences for the trafficker's business.

In Peru, those conducting counterdrug programs learned to monitor coca base, the principal commodity of the illicit coca business. The programs compared prices with break-even production costs and measured market growth and decline. These measures provided a very sensitive indicator of true operational consequences within Peru; however, they did not provide a measure of impact within the United States. In Chapter V, we examine the economic and activity indicators in the U.S. including street price and purity, and frequency of casual use. During the period (1990 to 1997) that Peru was the principal supplier of coca base to the U.S., one would expect that large disruptions of Peru's base market and smuggling activity would be observable in the U.S. market.

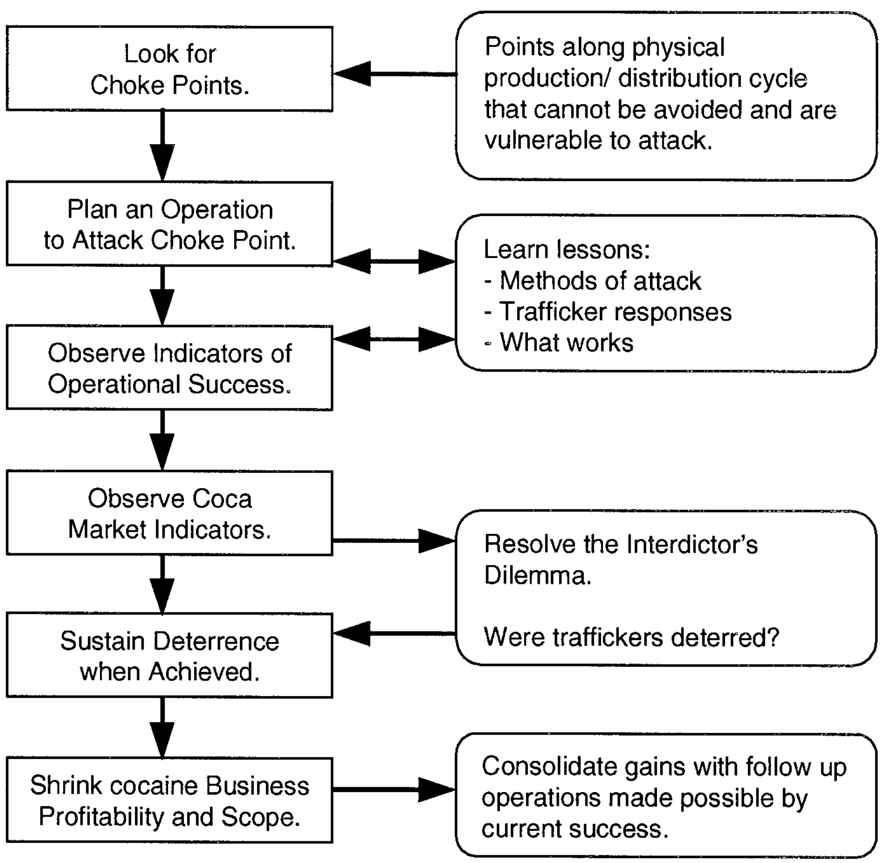


Figure III-1. Steps in Conducting a Major Interdiction Operation

B. PRICE, COST, AND TRANSPORTATION OF COCA BASE

In Peru, base price movements alone indicate that interdiction operations have an effect, while prices relative to estimated costs of production measure the damage to the profitability of the illicit coca business. Similarly, understanding the investment and projected additional revenues necessary to motivate planting new coca provides a means of anticipating structural change resulting from operations. A more detailed understanding of the air transport contractor's fees, expenses, and role in relationship to the trafficker who organizes the exchanges of coca base clarifies the higher-level business picture.

1. Coca Base Price Time Series

Before the 1990s, Peru's coca farmers were dazzled by the profits from very high crop prices, which forms a backdrop for subsequent changes and expectations. Prices for coca base were very high in the early 1980's, but dropped significantly between 1983 and 1989. Cuanto SA (Ref. 18) consolidated several sources to estimate prices for a kilogram of base. Initially in 1980, they were $4,600 per kilogram, falling to $3,150 by 1986 and to $1,200 by 1988. This probably reflected competitive pressure as production caught up with demand. In 1989, during the Colombian crackdown and U.S. President Bush's "War on Drugs," prices fell further to the $500 range after the U.S. and Peru established the Santa Lucia Base (SLB) in the heart of the Upper Huallaga Valley, causing significant disruption of the flights into and out of this largest of the growing regions.

In the 1990s, three alternative development and monitoring organizations collected monthly base price data: the United Nations Drug Control Program (UNDCP), the U.S. Agency for International Development (USAID/Peru) Management Information System (MIS), and the Government of Peru's Proyecto Especial Upper Huallaga (PEAH). As one can see from Figure III-2, these price series generally rise or fall together.

Data for all three of these price series are survey responses, not actual prices, and are meant to be judged in relation to each other over time as a means of discerning trends. The price data generally come from researchers and development agency workers who ask coca growers the "going price" for coca and its derivative products as a means of measuring the competitiveness of alternative crops. The response may or may not be an actual transaction price. These development agency workers request prices for leaf, paste, base, and HCL, although coca growers most often do not sell paste or leaf. The prices for the different products correlate highly, but not perfectly. For this reason, it is

important to know which product the majority of coca growers sell, as a means of examining the product prices that best reflect the market. Based on interviews with the researchers in Peru, coca base was the most common end product sold by Peruvian growers in the 1990s.

In 1992, the Peruvian Government Institute for National Development (INADE) in the Ministry of the Presidency began collecting coca price data through PEAH. These data are the medians of approximately 10 to 15 monthly observations from various municipalities in the Upper and Central Huallaga Valley. Early on, the USAID/Peru assembled a time series using available data from various sources including DEA, UNDCP, and PEAH, but now USAID uses PEAH as the only data source in its MIS.

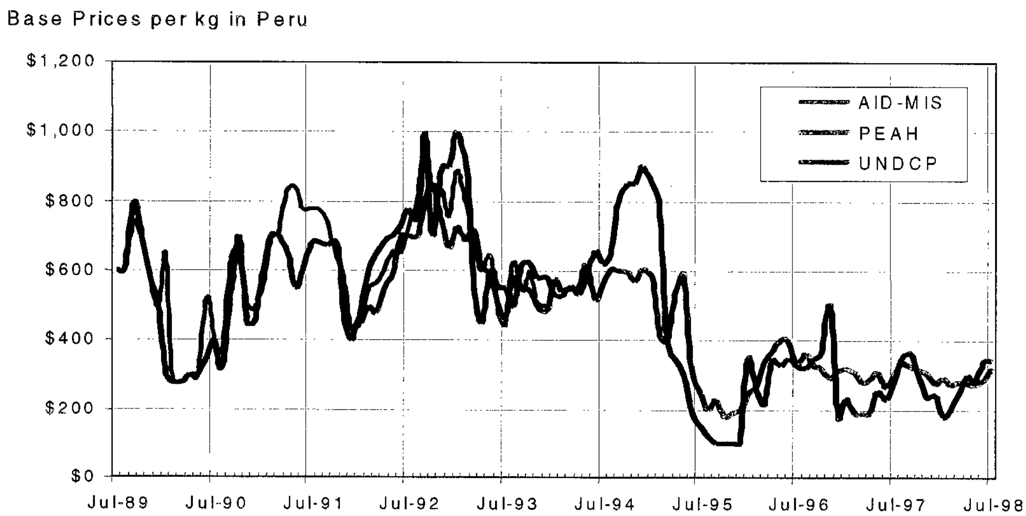


Figure III-2. UNDCP, USAID-MIS, and PEAH Coca Base Price Series for Peru

The UNDCP price data are averages of approximately 40 monthly survey responses gathered by field workers near UN alternative development sites in the Apurimac, Covencion, Cusco, and Upper Huallaga Regions. The number of observations varies over time, and the UNDCP Upper Huallaga data are occasionally drawn from the same locations as PEAH.

Other sources for coca prices are not included in this study because they add little to the selected series. These include the coca eradication project, "Proyecto Especial Control y Reduccion de Cultivo de la Coca en el Alto Huallaga" (CORAH), which collects data sporadically, and the Government of Peru's coca monopoly, "Empresa Nacional de la Coca" (ENACO), which buys legal coca. Our data sources are more

representative of the illicit farmgate base prices, which do not mix in licit prices or elevated illicit prices for base near borders in transit to Colombia.

a. Variability of Coca Prices

Prices for coca and its derivatives vary over time and geography, which demonstrates the difficulty of integrating a market in this rugged, and often lawless, terrain:

- Different areas have unequal access to chemicals and processing skills.
- Some areas are closer to the Peruvian border or face lower transport risks.
- Insurgents are more active in some areas.
- Specific trafficker buyer organizations and relationships dominate each area.

Because all of these factors change over time and cause dispersion in prices and quality of product, no single price figure can be regarded as the universal measure of the current price coca products in Peru. However, the price series we used were obtained from the primary growing regions, were consistently collected (except where otherwise noted), and agreed with accounts from other researchers who lived and worked in these areas.

The impact of these variations can be estimated by examining the month-to-month fluctuations. These fluctuations are consistent with the expected variability among sampled prices and the stabilizing effect of taking the median. Fortunately, the impacts of interdiction cause much greater discontinuities than the month-to-month fluctuations. Extracting these discontinuity features from the base price time series by visual inspection was sufficient for our analyses.

b. Consistency Between PEAH and UNDCP Price Series

Figure III-2 shows that the UNDCP data range nearly half again as widely as do the PEAH prices. Since Table II-6 showed that the Upper Huallaga Valley had the least decline in cultivation from 1995 to 1998, PEAH prices from the Valley would be expected to be more stable than the UNDCP prices, which were more widely sampled and are more representative of Peru as a whole.

The largest discrepancy between the UNDCP and PEAH data occurred from May 1994 to early 1995. Those in the U.S. Embassy in Peru funding the PEAH data collection attribute this discrepancy to an interruption of U.S. support to coca price data collecting during that period. This suspension of data collection occurred because the Government of Peru (GOP) insisted on employing lethal force if suspected trafficker

aircraft did not land and submit to inspection; USG policy, however, required a legal finding to determine whether this lethal interdiction could be reconciled with U.S. and international law. Until this finding was completed and approved by the U.S. President in December 1994, any support to a lethal engagement by U.S. officials might expose them to prosecution. By contrast, the UNDCP coca price data were collected without this interruption.

Overall, the three data series in Figure III-2 represent the most comprehensive measures of illicit coca prices. Of these three series, the UNDCP price series is based on the most observations and has enjoyed uninterrupted data collection support. For these reasons, we adopt the UNDCP nominal base price data to evaluate significant events disrupting the coca market and to resolve the interdictor's dilemma for the illicit coca business in Peru. We will also use the PEAH data during 1996 and 1997 to estimate the sustained minimum price necessary to nearly maintain coca base production, assumed to be close to the cost of production, because of the relatively modest rate of decline in cultivation for the Upper Huallaga Valley.

2. Costs of Producing Coca Base

Knowledge of processing costs for different stages of cocaine production provides a useful gauge to judge the profitability of coca growing and trafficking at a given price. There is no set cost for production because these costs vary. Some coca growers hire a few laborers, while for others the work is entirely a family operation. Also, coca growers may buy processing supplies legally, on the black market, or get them free from traffickers.

The Cuanto SA (Ref. 18) variable cost data for each production stage provided the most comprehensive study of costs for that time. Their study tabulated the amount of labor and supplies necessary at each stage of production and estimated lowest costs based on the licit market values of labor and supplies. The Cuanto SA estimates are sunken farmgate costs because coca growers produce base before it is picked up by a mid-level collector or a trafficker. Assuming that each product in the process is purchased at commercial market prices, rather than at a smuggler's markup price, results in minimum cost estimates for each product. In reality, some base producers buy leaf or paste from coca growers at the market price, which results in a higher process cost. During 1994, the DEA conducted Operation BREAKTHROUGH, an analysis of the productivity of Peru's coca farms and chemical processing methods. Their analysis describes the prevalent method of processing – to go directly from leaf to coca base. This is unlike the

process Cuanto SA describes as common in 1989, which included an intermediate coca paste stage. We, therefore, use the farmgate leaf and unit input price data from Cuanto SA and apply these to the processing methods described in Operation BREAKTHROUGH. We also compare these with the Cuanto SA price estimates employing the earlier processing methods.

Table III-1 summarizes our estimates of the costs of farming, harvesting, and chemical processing to produce coca base in 1989, 1992, and 1993. The percentage resulting from labor declined from 83 to 75 and then down to 66, which meant a diminishing share going to the farmer and worker. Chemical prices rose the most while chemist wages rose in 1992 only to fall sharply in 1993. Two events contributed to this variation. In August 1990, President Alberto Fujimori of Peru allowed the Peruvian currency (the Sole) to float to international market values. This "Fujishock" apparently doubled base prices and increased the cost of imported chemicals even more.[1] The second event was the beginning of operation Support Justice (SJ) IV between 1992 and 1993. This apparently cut in half the labor rates for specialized tasks, such as "chemist."

Although prices were somewhat volatile during 1992, they offered little profit over production cost estimates within the uncertainties concerning the type of process, the location, and source of the cost data. For example, Cuanto SA estimated the price per kilogram as $675, versus production costs of $677. Using the same method as Cuanto SA, the USAID/Peru study (Ref. 37) estimated prices as $675 and costs as $651. Assuming processing directly from leaf to base as DEA reported, production cost would have been $580 per kilogram while an average of PEAH price medians across sample locations yielded $644 per kilogram for this period, a $64 markup. UNDCP prices averaged $792 through this peak period, but included regions outside the cost estimate.

From April to September of 1993, after the Cuanto SA study cutoff, the PEAH prices remained constant but relatively low due to SJ IV, averaging $551. The UNDCP prices closely agreed, averaging $545 during this period. These two averages are remarkably close to the estimate of the "cost" of direct production of base, $546. The

---

1 On 8 August 1990, President Alberto Fujimori removed price subsidies and floated the exchange rate, increasing monthly inflation to 400 percent compared with 38 percent before. This "Fujishock" increased the price of gasoline 3,000 percent and food prices rose from 500 to 1,000 percent, and one expert reports that it doubled the variable costs of coca leaf production (Ref. 38). The Economic Section of the U.S. Embassy in Peru reported (Ref. 39) consumer prices rising steadily with a 56 percent jump from December 1991 to December 1992, a 40 percent increase in 1993, followed by relative stability of only a 16 percent rise in 1994.

similarity in these independent estimates indicates that, during stress, the farmers, laborers, and chemists appear to work without a separate "profit." We also conclude that, during periods of stress, PEAH prices in the more stable Upper Huallaga Valley production areas reflect the labor and material costs of production for Peruvian farmers.

Table III-1. Costs of Base Production During the Early 1990s

			Unit Price			Cost per Kg of Base			Cost Ratios	
	Units	Quantity	1989	1992	1993	1989	1992	1993	1992/ 1989	1993/ 1989
Leaf										
Wages	per kg	400	$0.39	$0.62	$0.54	$156.00	$248.00	$216.00	1.59	1.38
Chemicals	per kg	400	$0.08	$0.12	$0.13	$32.00	$48.00	$52.00	1.50	1.63
Transport	per kg	400	$0.07	$0.07	$0.07	$28.00	$28.00	$28.00	1.00	1.00
Leaf Subtotal	kg	400	$0.54	$0.81	$0.74	$216.00	$324.00	$296.00	1.50	1.37
Chemicals for Base										
Sulfuric Acid	liters	3	$3.08	$8.60	$10.00	$9.24	$25.80	$30.00	2.79	3.25
Lime	kg	15	$0.15	$0.50	$0.20	$2.25	$7.50	$3.00	3.33	1.33
Kerosene	liters	90	$0.10	$0.58	$0.79	$9.03	$52.31	$71.33	5.79	7.89
K-Permang	kg	0.05	$6.15	$30.00	$30.00	$0.31	$1.50	$1.50	4.88	4.88
Ammonia	liters	1	$6.15	$10.00	$25.30	$6.15	$10.00	$25.30	1.63	4.11
Chem Subtotal						$26.98	$97.11	$131.13	3.60	4.86
Labor for Base										
Stompers	days	8	$4.62	$7.70	$7.20	$36.96	$61.60	$57.60	1.67	1.56
Assistants	days	3.49	$4.62	$7.70	$7.20	$16.15	$26.91	$25.16	1.67	1.56
Chemist	days	1.75	$32.33	$40.00	$20.40	$56.50	$69.90	$35.65	1.24	0.63
Labor Subtotal						$110	$158	$118	1.45	1.08
Leaf to Base	kg	1	This Report			$137	$256	$250	1.87	1.83
Total for Base	kg	1	This Report			$353	$580	$546	1.64	1.55
Total for Base	kg	1	Cuanto SA, 1993			$302	$677	$470	2.24	1.55
Total for Base	kg	1	USAID/Peru, 1993			NA	$651	N/A	N/A	N/A
Base Prices	kg	1	Cuanto SA and PEAH			$1,000	$675	$551		
Base Prices	kg	1	UNCDP			$633	$792	$545		

Notes: Unit price data taken from Cuanto SA, 1993 (Ref. 18).

400 kg batch and conversion to one kg coca base at 84% purity is taken from Operation BREAKTHROUGH in Peru, 1997, which analyzes processing in 1994 (Ref. 17).

Labor was scaled from the quantities in Cuanto SA to those in Operation BREAKTHROUGH.

Fujishock in August 1990 refers to Peru floating their currency and doubling most prices.

Observations about cost ratios: Fujishock sent imported chemicals rapidly inflating. Labor rises and falls with market demand. Chemist wages were most volatile. Cuanto SA and USAID/Peru are both based on leaf to paste to base production vice leaf to base as in DEA study.

Coca Base prices taken from Cuanto SA for 1989 and 1992. 1993 base price from constant period Apr-Sept 93 (end of Cuanto SA study) was $551.

Note that CY92 base prices averaged $644 according to this study.

At these 1993 prices, the planners of SJ IV expected coca production to decline, but it did not. Production and average traffic remained constant. Following the shoot-

down policy, however, base prices fell below $200 per kilogram as inventories competed with new production in the absence of buyers. Farmers without food crops went hungry during this period; clearly coca agriculture was a net loss at these prices. Because the shelf life of coca base is only 6 months and because the interdiction forces temporarily stood down in December 1995, prices rebounded to a stable but low level. From 1996 through 1997, the PEAH base prices remained very steady and averaged $317 ±$39. By contrast, UNDCP base prices reflected the turbulence throughout Peru with large variation around a lower price, $288 ±$80. Because of the lack of realistic employment alternatives, some price stability, the desire to preserve sunk costs in coca cultivation, and possible prospects for better times, most Upper Huallaga Valley farmers continued to produce at these prices with only moderate abandonment of fields. Thus, $317 per kilogram must be approximately the subsistence level for the most efficient coca farmers and base processors in Peru.

The UNDCP price series in Figure III-2 systematically sagged below the PEAH prices during 1996-97 and, as we saw in Table II-6, illicit cultivation declined precipitously during this period for most other regions of Peru. Alternative development expanded in the Apurimac Valley because alternative crops brought in roughly 60 percent of an illicit coca crop.[2] Thus, the following conditions contributed to farmers' willingness to abandon their coca crops while base prices were in the $300 range:

- Low prospects for higher and stable base prices in the near future
- Realistic alternative development opportunities
- Increased government monitoring and police presence accompanying infrastructure development.

Cost comparisons between different timeframes are complicated by the high inflation rate in Peru and lack of an inflation index for coca regions. Nevertheless, the post-shoot-down policy subsistence prices are only about 60 percent of the previous full production price levels during SJ IV; this large ratio over a short time span should provide useful comparison.

3. Investment in New Cultivation

Investment in new cultivation is yet another indicator of the profit margin in coca production. When base prices were greater than $2,000 per kilogram during the early

---

2 Personal communication from visit to USAID in 1999, sharing a result of a study in progress.

1980s, farmers planted intensely and cultivation expanded rapidly. During SJ IV, replacement planting was common even in outlying areas such as the Lower Huallaga Valley. After the enforcement of the shoot-down policy, prices collapsed, and many farmers abandoned their fields especially in outlying regions. In the Upper Huallaga Valley where decline was only moderate, some zones showed new dense cultivation.

An examination of the economics of new cultivation suggests that prices would have to exceed $800 per kilogram and remain there for 4 years to promote significant new cultivation. We arrive at this threshold in the following manner. Estimates of the costs for installing one hectare of coca, including labor and supplies, range from $2,373 in 1994 (Ref. 40) to $2,800 in 1996 (Ref. 41). After a 2-year maturation period, the new field might produce the Peruvian average of 1.83 metric tons of leaf per hectare. Recovering this investment in years 3 and 4 would require a price increase of at least $0.68 per kilogram of leaf for those years. Assuming 400 kilograms of leaf per kilogram of base, this is an additional $273 per kilogram of base for 2 years. With the comfortable break-even price of coca base around $550, farmers would have to expect a future price well over $800 to invest in new planting.

Altogether, we obtain the following scale relating to base prices in planting new coca:

- At over $1,100 per kilogram, farmers will recover the cost of new cultivation in a single year following the 2-year maturation process of newly planted coca. Therefore, extensive new cultivation can be expected if there are prospects for the market to remain high for 3 years.
- At $800 per kilogram and above, farmers will recover costs of new cultivation in 2 years but, again, the 2-year maturation process means they must believe prices will remain high for 4 years.
- At around $550 per kilogram, farmers will make a decent wage sustaining existing crops by replacing dead plants and tending healthy ones.
- At around $320 per kilogram, most farmers will stay in business but without investing in crop maintenance for the long term. This is at the brink of abandonment.
- At around $250 per kilogram, most farmers will abandon their fields unless there is good reason to believe that prices will recover within less than about a year.

4. Economics of the Air Transport

During air interdiction operations, the fees for transporting coca base to Colombia should rise abruptly. Cost data for air transport would measure the immediate impact on coca trafficking. The USAID/Peru (Ref. 37) study also gave a breakdown of the costs of flying coca base to Colombia in mid-1993 during SJ IV; see Table III-2. A typical 500-kilogram load costs $86,000 to transport, that is, $172 per kilogram. Seventy percent of this cost is the pilot's fee.

During 1996-97 after the FD/SD policy enforcement, the U.S. Embassy in Peru reported in 1999 that pilot fees had risen to more than $200,000 per flight. There is, of course, a difficulty in recruiting pilots even at such a high fee, which is a topic for the next chapter. Upon adding the other transport fees from Table III-2, this translates into $452 per kilogram. Other reports include much higher offers to pilots and substantial bribes to personnel involved in interdiction operations. In the next chapter, we see that, even with high fees, trafficker organizations could not restore the air-bridge because too few were willing to face the interdiction risks.

Table III-2. Cost of Air Transport across the Air-bridge for a 500 kg Load in 1993

	Labor		Costs		
Item	Man-Days/ Flight	Daily Wage	500 kg Load	Cost/Kg	Percent
Landing fees	N/A		$15,000	$30	17.4%
Local transport	100	$50	$5,000	$10	5.8%
Security	20	$250	$5,000	$10	5.8%
Radio operator	1	$500	$500	$1	0.6%
Accountant	1	$500	$500	$1	0.6%
Pilot and aircraft	1	$60,000	$60,000	$120	69.8%
Total			$86,000	$172	100.0%

Data Source: USAID/Peru, Peru's Cocaine Economy, 1993 (Ref. 37).

C. EFFECTS OF AIR INTERDICTION OPERATIONS ON COCA MARKETS

Now we review what happened during the major interdiction operations that affected Peru. We examine the evidence for impacts on the coca markets. Whenever appropriate, this summary also discusses some of the important collateral events of those time periods, contrasts the operational periods from those between operations, and describes the critical requirement for cooperation between the U.S. and Peru.

Figure III-3 provides a timeline spanning the four operational periods that we will consider in more depth. It also shows the number of verified air interdictions for each month from 1990 onward. Notice how few there were, at most eight in one month. For comparison, we repeat the UNDCP and the credible portion of the PEAH price series for coca base and our estimates of producers' costs for base. Segments of this figure and a chronology of major events are included in the introduction to the description of each operational period.

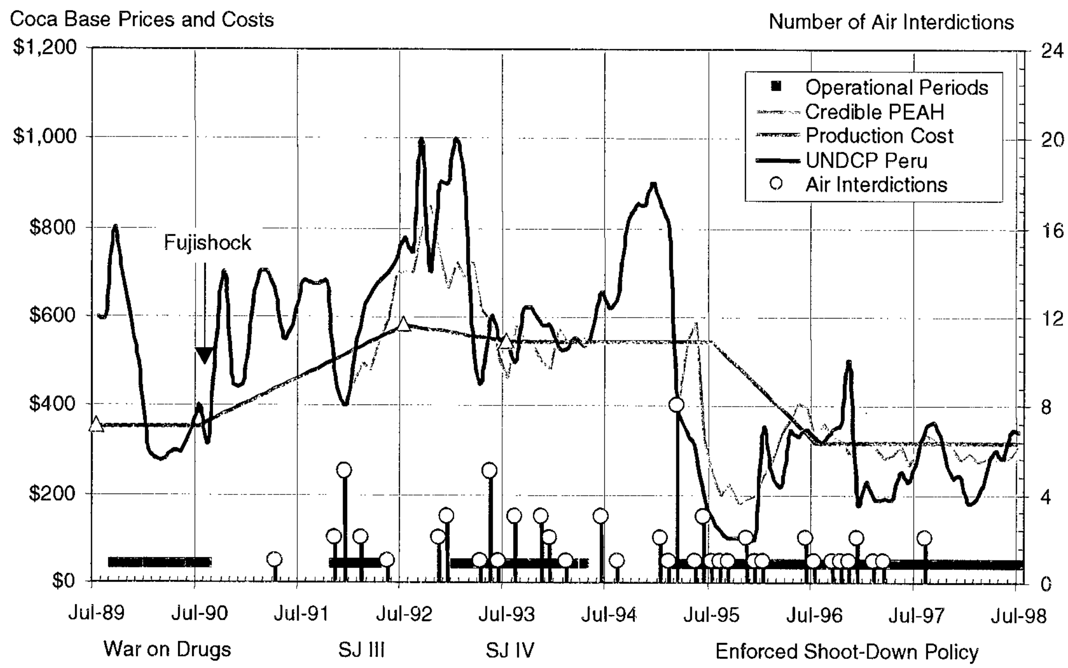


Figure III-3. Operational Periods, Air Interdictions, and Peruvian Base Prices and Costs per kg

This summary was assembled by one of the authors of this report, who spent 4 months in Peru as an Embassy staff intern researching the causes of the collapse of the coca economy. He had access to all of the counterdrug and alternative development teams at the U.S. Embassy in Peru and spent significant time with original Peruvian sources. In addition to reviewing both unclassified and classified materials, he interviewed those analysts in depth. He was also able to interview Peruvian journalists, academics, and independent alternative development agency staff and was given access to many of their archives. Although this process uncovered many collateral events that influenced the illicit coca business in Peru, only the air interdictions and eventual severing of the air-bridge can coherently explain the collapse of Peruvian coca market. In subsequent trips to the U.S. Embassy in Peru and to the UNDCP office in Lima, this

research team encountered universal agreement of all parties that the interdiction of the air-bridge caused the collapse of the coca market. The low prices were due to the air-bridge interdictions, and voluntary manual eradication occurred only when the prices were low. They also emphasized that keeping coca prices low is the essential precondition to the success of alternative licit economic activity and increased security in the former coca cultivation regions.

In past years, many events have affected the coca market to varying degrees. Lee (Ref. 42), Clawson and Lee (Ref. 43), and Riley (Ref. 3) list several of these events, and we have identified others, which will be presented as a timeline associated with each operational period. In order to identify past events that have had the most significant impact on the market, a methodology must be established *a priori* for distinguishing significant price changes. As we have seen, the UNCDP prices exhibit large, repeated, and abrupt rises and plunges. We associated these changes with precursor events that might have caused such changes. Repeatedly, in several air interdiction operational cycles, prices fell as air interdiction operations were initiated and recovered as they relented. Even then, because correlation does not necessarily imply causation, we matched the price changes with relevant anecdotal evidence in order to verify the association with air interdiction operations as the proximate cause rather than other collateral events.

Four operations stand out in the collected research materials as significantly disrupting the Peruvian coca market:

- The Colombian crackdown began on 19 August 1989 and U.S. President Bush declared a "War on Drugs" on 5 September; by November, the crackdown had turned into an obsessive chase for Pablo Escobar and Jose Rodriguez Gacha (Ref. 44). In January 1990, the landing strip at the Santa Lucia Base (SLB) in the heart of the Peruvian growing region became operational for FAP/USG aircraft, which caused traffickers to alter their flight paths significantly into and out of the growing areas.
- Operation SJ III began in September 1991 in Colombia and in November 1991 in Peru; it ended on 29 April 1992.
- Operation SJ IV began in November 1992 in Colombia and in January 1993 in Peru; it ended on 1 May 1994.
- The resumption of U.S. detection and monitoring support for a potentially lethal interdiction endgame, began in January 1995 in Colombia, but effectively began for Peru in March 1995. There were substantial

reinforcements to sustain the operations in September 1995. These operations continue with only a brief stand-down in December of 1995.

As Figure III-3 shows, each of these operations is associated with a downward price trend of base prices. Consistently, the anecdotal evidence points to these four operations as the reason for drops in coca base prices.

Each of the four operations employed radar detection and monitoring to assist the Peruvian Air Force to interdict trafficker flights from Peru to Colombia. Figure III-4 maps the air tracks of suspected trafficker flights detected by radar sensors. For orientation, we also show the distinctive eastern Peruvian border. Most tracks originate in Peru's Huallaga Valley growing region, and all tracks eventually end in Colombia.

Figure III-4 compares the situations for 1991 to 1992, 1993 to 1994 during SJ IV, and the change of trafficking in 1995 after the enforcement of the FS/SD policy. It also shows the GBRs and the circular approximations to their detection ranges for aircraft at different altitudes. Tracks outside the GBR range were reported by airborne radars used for both detection and monitoring. The GBRs were located at Napo Goleras and Aracuara to the north and Yurimagues to the west of Leticia. Another radar that was temporarily deployed near Pucallapa is not shown.

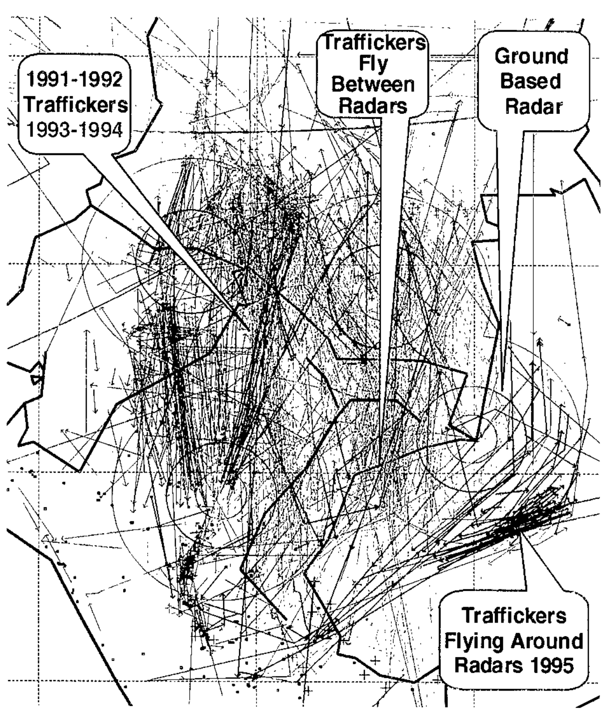


Figure III-4. Principal Air Trafficking Routes (Radar Tracks) from Peru to Colombia – Before and After the Shoot-Down Policy

The essential difference between these two traffic patterns is that the traffickers ignored the interdiction threat by flying directly through the area of coverage of GBRs in 1993 while they avoided the radars in 1995. During SJ IV, there was no lethal threat to backup interdictors' efforts to force down the traffickers. In 1995, with a lethal threat and dense radar coverage, traffickers attempted to fly between Napo Goleras and around Laticia – this latter referred to as the Laticia skirt.

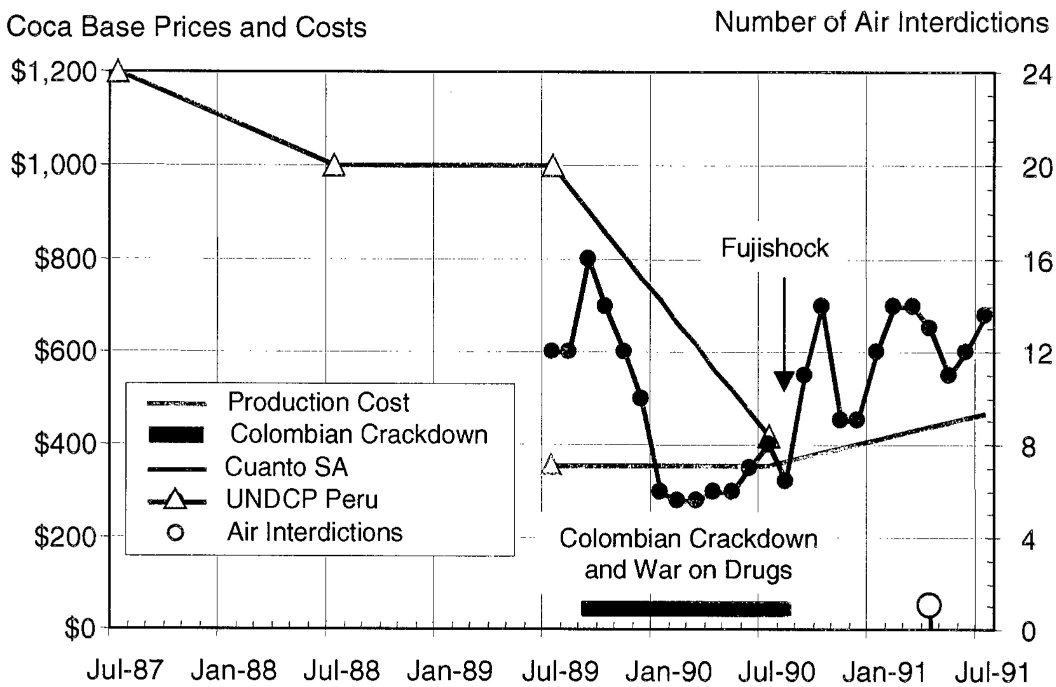
The reader should note that this summary repeats anecdotal evidence as it was presented in its referenced sources. This faithfulness to the sources often ignores the sometimes-obvious inconsistencies or conflicts among sources. Although it may confuse the casual reader, we believe that the net result is to reconstruct the pattern of events much as they were experienced as they unfolded, rather than with refined hindsight. The careful reader will see that alternative causes for the decline of coca cultivation were either minor and transient or did not form into a consistently repeated pattern as did the air interdiction operations and their impacts. The next chapter presents the quantitative analysis of available data on the air interdiction operations. In that analysis, numerical consistency and precision of the selected data are essential and addressed in depth. We describe the sources employed in these other sections as the data are introduced.

1. Colombian Crackdown

The events leading up to the Colombian Crackdown and President Bush's War on Drugs provide an informative background to the Peruvian air interdiction operations to follow. Figure III-5 and its associated chronology place this important transition period in context. Before July 1989, the scant data on coca base prices in Peru indicated a continuing decline from the over $4,000 per kilogram level of the early 1980s as the market was tightening up from overproduction. After July 1989, the UNDCP began systematic sampling of coca base prices in Peru and subsequently provided much more resolution of the relative changes in response to events. The chronology below Figure III-5 highlights some of the counterdrug operations in Bolivia, Colombia, and Peru during the 1980s. Primarily, these targeted coca processing with raids on laboratories, cultivation with eradication, and clandestine airfields with physical damage.

a. Sequence of Events

Before the Colombian crackdown, low enforcement intensity in Peru existed because of poor conditions caused by a guerrilla insurgency in the Upper Huallaga Valley



Note: The air interdiction times series only began in March 1991.

1979-80: Peruvian National Police Operation Green Sea targets UHV coca processing.
April 1983: CORAH begins coca eradication in the Upper Huallaga Valley.
1985-86: Peruvian National Police (PNP) conduct Operation Condor.
July-Nov 1986: U.S. Army-assisted Operation Blast Furnace in Bolivia.

1987

March: DEA initiates Operation Snowcap in coca-source countries.

1989

Feb-Aug: CNP Operation Primavera destroys some of Medellin Cartel's biggest labs.
Feb. 10: USG counterdrug (CD) activity in Peru suspended due to lack of security.
April 13: Peruvian Army deployed to UHV to combat Shining Path (AN August 1989).
Aug. 18: In Colombia, anti-drug presidential candidate Luis Carlos Galan is assassinated.
Aug 19: **Colombia begins crackdown** on cartels. 193 aircraft seized (returned in two months
Sept: USG delivers $65 million-worth in DOD assistance to Colombia.
Sept 5: **Bush declares "War on Drugs."**
Sept 8: **USG SLB becomes operational in heart of the UHV,** DEA Snowcap and CORAH operations resume.
mid-Sept: Record seizure in Los Angeles of 21.4 tons of cocaine (a few percent of world supply).
Sept 25: Fujimori rejects USG CD Military Assistance Agreement, claiming not enough emphasis is being paid to crop substitution and alternative development.
Dec 20: USG invades Panama to apprehend Manuel Noriega.
Dec 23: Peru suspends joint CD operations to protest USG invasion of Panama.

1990

January 5: **SLB landing strip becomes operational**, trafficker flights decline from 50-60 planes/week in July 1989 to 5 planes/week in Feb 1990 (Gonzales, p. 143).
April: Shining Path terrorists in the UHV began to put pressure on local traffickers to pay better prices for the coca derivative
Aug 8: Fujishock resulted from President Fujimori's decision to float the Peruvian currency.
Sept 25: President Fujimori refuses to sign USG $35.9 million military assistance agreement, protesting the lack of USG assistance toward crop substitution and alternative development program

Figure III-5. Base Prices and Costs Surrounding the Colombian Crackdown

(UHV) and the neglect of CD operations by the Peruvian Army's counter-insurgency strategy. On 10 February 1989, the U.S. Ambassador to Peru suspended USG CD activities because of a lack of security. USG emphasis shifted to building the SLB, a fortified compound near Uchiza in the middle of the UHV. The base had been under construction since early 1987. In September 1989, the base was operational and limited enforcement and eradication operations continued; in January 1990, a landing strip was opened at the base.

In 1989, events in Colombia spiraled into a national crisis. The Colombian National Police (CNP) began Operation Primavera with the support of the Colombian military and DEA special enforcement Operation Bolivar. Within 8 months, Operation Primavera resulted in record-breaking seizures and destruction of some of the Medellin Cartel's most important laboratories (Ref. 45; Ref. 46, p. 73). The Cartel retaliated by assassinating Colombian judges and police officials, culminating in the 8 July killing of Colombian Presidential candidate Luis Carlos Galan (Ref. 45, p. 177; Ref. 47, p. 14; Ref. 48). On 19 August, Colombian President Virgilio Barco declared war on the traffickers; the Colombian crackdown began. President Barco issued decrees reinstituting extradition of traffickers to the U.S. and confiscation of trafficker assets. By August, the CNP had detained more than 10,000 people and seized 134 suspected trafficker-aircraft (Ref. 49). The U.S. had already given the Government of Colombia a list of twelve U.S.-indicted Medellin and Cali Cartel traffickers and, on 25 August, pledged $65 million in helicopters and other equipment assistance (Ref. 50; Ref. 45, p. 177).

On 5 September 1989, President Bush declared a "war on drugs" condemning domestic cocaine consumption, commending the Colombians, and announcing that, when requested by drug-source nations, the U.S. "will for the first time make available the appropriate resources of America's armed forces" (Ref. 51). The war on drugs involved countering trafficker flights and boats in the Caribbean, building the SLB in the Upper Huallaga Valley of Peru, invading Panama, and providing support to the Colombians. This high level of intensity, however, could not be sustained. The Iraqi invasion of Kuwait siphoned off necessary military assets, the Colombian public tired of the intense violence between their government and the Medellin Cartel, and Peru's President Fujimori suspended joint counterdrug operations to protest the U.S. invasion of Panama. While in Colombia, of the 10,000 arrested in the first few days of the crackdown, 535 were retained and charged (Ref. 52). Between October and December 1989, the judiciary, because of lack of evidence, returned planes and other property. By November

1989, the crackdown had essentially turned into an obsessive chase for Pablo Escobar and Jose Rodriguez Gacha, regarded as the two most powerful traffickers (Ref. 44).

Colombians complained bitterly when the U.S. allowed the International Coffee Agreement to collapse, reducing the price of coffee by half. Colombia would lose an estimated $400 million to $500 million annually as a result of the price drop (Ref. 53, p. 82). On 10 August, Mayor Marion Barry of Washington, DC, was acquitted of all but one possession conviction out of a 14-charge indictment. The verdict outraged Colombians, who felt they were paying too high a price to interdict the drug while consumption in the U.S. went virtually unpunished (Ref. 54; Ref. 55).

On 5 September 1990, Gaviria offered traffickers who turned themselves in and confessed their crimes reduced prison sentences and a chance to avoid extradition to the U.S. (Ref. 56). After indirect negotiations between traffickers and the government, Gaviria decided that "extradition will be retained as a secondary instrument in the drug war" and the GOC passed a law on 14 December effectively placing a moratorium on extradition (Ref. 57, 1991, p. 96). On 18 December, Medellin Cartel leader Fabio Ochoa Vasquez became the first to surrender (Ref. 58). On 19 June 1991, the head of the Medellin Cartel, Pablo Escobar, surrendered and entered "prison," which was a house of his own design. By July, Gaviria had an 80 percent approval rating for getting the drug lords to surrender and halt the violence (Ref. 59).

During January 1991, FAP fighters were deployed to SLB, where they fired only warning shots. The FAP had a surprisingly effective air-interdiction program aimed at curtailing drug flights in the UHV despite their lack of radar. Pilots shot down one plane, from which two pilots ran away, and forced another to land at the SLB yielding a significant amount of cocaine. The operation ended 5 February (Ref. 60). In April 1991, the FAP was charged with direct control of airports and airstrips in coca zones. The major obstacle to increased interdiction effectiveness was the absence of radar.

b. Market Effects

During this period, so much was happening – air operations, pursuit of druglords, and major transit zone interdiction efforts – that it is impossible to retrace back from the market impacts in Peru to simple causes. However, we now know the relative importance of these kinds of operations because further information has become available. Operations over the UHV in 1992-93 and in 1995 show the dramatic effects of limiting base flights. Thus, the most significant of the many events might have been the opening of the SLB, disrupting a large percentage of the base flights. In Peru, Gonzales

(Ref. 34) reports that with the establishment of a landing strip for interdiction aircraft in January of 1990 at the SLB, illicit air traffic fell from 50 to 60 planes per week to only 5 planes. This rapid decline of air movements is consistent with the sequence of events lending to the collapse of the air-bridge several years later. Nevertheless, these aspects of the Colombian crackdown period confound each other in trying to identify causation. These other events did not prove much about the value of attacking the air-bridge carrying coca base from Peru to Colombia; rather, they are merely consistent with other evidence that the air-bridge is a vulnerable choke point in the illicit coca trade.

Figure III-5 shows Fujishock soon followed by an abrupt rise of base prices in August and September of 1990. However, even if the entire price rise was due to Fujishock, it was only a factor of 2, not the factors of 5 to 30 reported in the areas where the government measured the increases.

Before the crackdown, the price of coca derivatives in Peru had been steadily decreasing since 1978 because of a rapidly increasing supply of product at all levels of the process (Ref. 61, 1982, p. 21). Traffickers in Peru produced high-quality cocaine for the U.S. market on a small scale because they were hampered by an inability to accumulate sufficient quantities of ether and acetone, two necessary chemicals for producing HCL (Ref. 61, 1982, p. 24). In 1988, native communities were still "bewitched" by the profits to be made by producing coca paste. Coca profits were eight times those of other crops. By September 1989, U.S. DEA and Customs officials observed that large air shipments of cocaine from Colombia to the U.S. had slowed to a crawl. They attributed the slowdown to the aircraft seizures in Colombia (Ref. 52), but a large air defense system had also been put in place, and no one understood the significance of the disruption of flights in and out of Peru. By late 1989, traffickers in Colombia were producing cocaine at 25 percent of their pre-August level (Ref. 53, p. 74). Base shipments from Peru to Colombia dropped as well by about half. Tons of base were reported to be piling up in the jungle (Ref. 62). Large backups of base are consistent with later results.

After the crackdown in August 1989, the press reported that coca profits were only twice those of other crops. Economic activity in the UHV declined by 60 percent (Ref. 63). Several sources noted the reduced prices in Peru and attributed the drop to low demand because traffickers were "lying low" in Colombia (Ref. 64; Ref. 65; Ref. 66). As a direct result of the crackdown, there was a reported 75 percent reduction in cocaine processing and trafficking activities in Colombia (Ref. 53, p. 21). By July 1990, prices reportedly reached their lowest point in two decades (Ref. 67). Traffickers without

money from the Cartels in Colombia took base from Peruvian coca growers on credit (Ref. 68, p. 4). DEA officials suggested that the crackdown was having powerful and possibly long-term market effects (Ref. 66).

Some Peruvian experts had a different explanation for the price drop. In an effort to refute a claim attributed to U.S. Embassy officials in Peru that Peruvian enforcement operations contributed to the drop, these experts attributed the price drop to a glut in the market resulting solely from overproduction (Ref. 67). At the time, one could not assess the impact of overproduction; however, overproduction was not a major factor in subsequent market collapses while air operations clearly were.

One of the reasons the price recovered in 1990 is that the CNP began to focus solely on tracking down specific Medellin Cartel members. They shifted their emphasis from seizing jungle labs and assets to an extradition campaign. Independent traffickers filled the market gaps left open by the preoccupied Medellin Cartel members (Ref. 39; Ref. 69; Ref. 70). By March 1990, cocaine production in Colombia was at 80 percent of what it had been before the crackdown (Ref. 53, p. 74). By October 1990, prices had begun to rise (Ref. 53).

The Colombian Crackdown significantly influenced coca processing in Peru as growers began hiring chemists to produce coca base directly from leaf instead of going to paste as an intermediate step. Increased processing of coca in Peru resulted from several factors: lower prices in Peru and high enforcement intensity in Colombia combined with low enforcement intensity in Peru. These structural changes resulted in significant product purity drops that were observed even in the United States.

As prices dropped during the late 1980's, coca growers found paste-processing necessary to stay in the business. By 1991 they were investing in additional capital and began processing dry and fresh leaf into paste (Ref. 71). Traffickers thought the same way. HCl production in Peru noticeably increased during the late 1990's (Ref. 72), but it was still only a small percent of the total possible from the Peruvian production. Coca-grower paste and base processing increased more than trafficker HCl processing mainly because of the scarcity of chemicals required to process HCl. Processing to paste and base uses easily available chemicals. Kerosene, sulfuric acid (in car batteries), potassium permanganate, and ammonia are produced in Peru and have too many commercial uses to be controlled. By contrast, ether and acetone, both required to process coca base into HCl, have few commercial uses and are monitored by the GOP (Ref. 57, 1988, p. 104).

c. The Sendero Luminoso and the "Fujimori Doctrine"

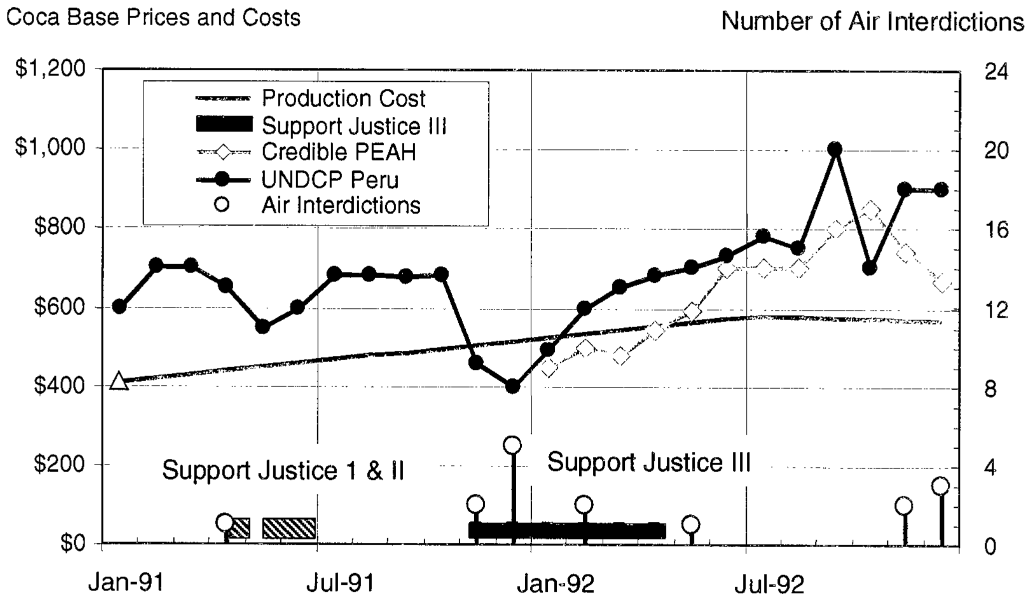
Another factor shaping the course of events in Peru emerged at this time. A Marxist guerrilla movement was benefiting from the increasing lawlessness of much of Peru's interior where illicit coca was cultivated. This Sendero Luminoso (SL or "Shining Path") terrorist group drew support from coca growers in the UHV by protecting them from the "repercussion" of police enforcement and CORAH coca eradication while negotiating higher prices with the Colombian traffickers, in return for "tax" on profits. By 1990, many of Peru's remote regions were declared "emergency zones" and placed under the control of political-military zone commanders. With the top priority for Peru's government to counter the terrorist threat, zone commanders attempted to separate the coca farmers from the SL, a strategy that failed.

Simultaneously, President Fujimori shifted policy toward a "Fujimori Doctrine" of attacking the traffickers rather than the coca farmers. Under this doctrine, Fujimori refused U.S. military assistance unless the aid package included funds for crop substitution and alternative development programs. Also, crop eradication programs became more voluntary in exchange for alternative development assistance including infrastructure development and increased government access. Even eradication on government property was not pursued with force. If illicit farmers fired upon the eradicators, the eradication teams simply left. Jumping ahead to the point that air interdiction finally blocked most Colombian traffickers from being able to buy coca base, the Peruvian farmers blamed the traffickers for not coming, and many looked upon the collapse of the coca base market as an "act of God."

2. Operation Support Justice III

Interdiction consists of surveillance and apprehension. All of the SJ operations involved U.S. detection and monitoring (D&M) assistance along with ongoing intelligence gathering by DEA and funding for data collection by alternative development agencies. The U.S. Department of Defense (DoD) is precluded from the apprehension endgame because of laws restricting military participation in law enforcement activities (Ref. 73). These restrictions come from the Posse Comitatus Act, passed at the end of the Civil War when U.S. military operations in foreign lands were restricted to supporting the host nation forces.

Figure III-6 and its associated chronology show the period of operations for SJ III and an associated significant dip in coca base prices.



1991
April 23: Training operation SJ I begins and lasts 5 days.
23 May: Training operation SJ II begins and ends 30 June.
June 19: Pablo Escobar, Medellin Cartel leader, surrenders to authorities.
Sept: Operation SJ III begins in Colombia.
Dec: **Operation Support Justice III** begins in Peru.
1992
April 5: Autogolpe (self-coup) – Fujimori dissolves Peruvian Congress and suspends the Constitution.
April 24: FAP fighters fire upon an USAF C-130 flying a routine, GOP-approved drug mission, resulting in the death of one crew member.
April 29: **Support Justice III** ends.
July 22: Pablo Escobar escapes.
Sept 12: Abimael Guzman, leader of the Sendero Luminoso (SL) or "Shining Path" is captured. Strength and image of SL deteriorates.

Figure III-6. Coca Base Prices and Costs Surrounding Support Justice III

a. Sequence of Events

Operations SJ I II had primarily been for training purposes. During SJ I, from 23 April to 28 April 1991, U.S. Air Force E-3As, which are the Airborne Warning and Control System (AWACS), and other radar-equipped planes were deployed to track trafficker flights in Colombia. SJ II was a more extensive D&M effort. From 23 May to 30 June 1991, more than 60 D&M missions were flown in conjunction with host nation interceptor planes. The results were tremendous; several planes were forced to land and 42 aircraft were confiscated (Ref. 74, p. 32). Interceptors were firing only warning shots.

Although SJ I and II were short training operations and not major operations, one can see that base prices did dip slightly during this period.

Operation SJ III began in Colombia September 1991 and in Peru November 1991. The delay in Peru was because of Peruvian border skirmishes with Ecuador from September to October 1991 that nearly led to war. Once the conflict cooled, SJ III began in Peru. SJ III was the first time GBRs were brought to Peru. Two U.S. Southern Command (SOUTHCOM) GBRs were contracted out for 90 days starting 25 November, and placed in Andoas and Iquitos. The FAP operated out of Andoas and Iquitos with U.S. radar support to intercept five Colombian planes illegally operating in Peruvian air space, resulting in the seizure of 600 kilograms of coca base (Ref. 75). On 6 December 1991, a Colombian plane ignored requests to land in Andoas and was shot down over the northeastern Peru jungle. This was the first U.S. radar-assisted shoot-down in Peru.

The initial 90-day deployment was extended another 2 months when USG officials realized they would be pulling out the radars 2 days after Bush's 23 February 1992 San Antonio Counterdrug Summit. On 24 April 1992, Peruvian-American relations deteriorated when FAP fighters fired their machine-guns upon a U.S. Air Force C-130, resulting in the death of one crewmember. The C-130 had been flying a routine, Government of Peru-approved mission, but ignored communication requests from the fighters. The Government of Peru apologized for the incident (Ref. 76). On 25 April 1992, USG-supported radar operations shut down, and SJ III effectively ended (Ref. 77). That the shutoff occurred about the same time as Fujimori's takeover of the government, Autogolpe, and the C-130 incident was coincidence.

b. Market Effects

Air interdiction of trafficker aircraft had a tremendous impact on the coca market in Peru. SJ III air interdiction operations forced an accumulation of coca paste and base in warehouses while prices for leaf, paste, and base dropped significantly (Ref. 74, p. 32). During the 5 months of SJ III, pilot fees rose dramatically. Interdiction effectively doubled the cost of flying a planeload of base out of Peru, reaching as high as $40,000 (Ref. 78). Thus, pilot fees were less than $20,000 per load before SJ III or about $40 per kilogram. Figure III-6 shows an abrupt decline soon after SJ III began, and the PEAH prices of the UHV remained low throughout SJ III while UNDCP prices that included other areas rose somewhat before the end of SJ III.

The price decrease for coca coincided with the seasonal trends associated with the December to March rainy season, when prices drop because rain harms dirt landing strips

and makes flying more difficult. This price decrease, however, was observed to be larger than usual and was generally attributed to the interdiction operations (Ref. 74, p. 124). The interception of planes flying out of the UHV also contributed to a general dispersion of the coca market to areas surrounding the UHV. Traffickers adapted to the radars by flying at lower altitudes, at night, and using multi-ship flights (Ref. 74, p. 33). The use of clandestine airstrips dispersed into outlying areas also increased (Ref. 57, 1993, p. 123). In addition to Sendero Luminoso violence, their forced taxes, and a coca fungus outbreak, the arrival of buyers in former coca boom towns like Tingo Maria, Tocache, and Uchiza was becoming an increasingly unpredictable event. The people who were not migrating to other places to grow coca were switching back to legal crops (Ref. 79, p. 40).

A comparison of the UNDCP and PEAH price series reflect these differences. The PEAH data, collected exclusively in the UHV where SJ III had its impact, were much slower to recover than the UNDCP data, which were at that time collected throughout Peru. In fact, the more rapid rise of UNDCP price series might be attributed to the increased value of the remaining coca base outside of the area of SJ III operations.

With the end of SJ III, Peruvian Air Force interception of narco-aircraft became much more complicated and demanded greater air operations resources. One pilot commented, "We're blind … we don't have planes with radar. We can't work at night." Coca prices rose quickly, and coca growers began expanding cultivation (Ref. 80). Although cultivation continued to decline in the UHV – dropping from 61,000 to 34,000 hectares – cultivation in other regions increased from 68,000 to 75,000 hectares.

c. Corruption and Guerrillas

The increase of coca prices following the end of SJ III has also been attributed to increased military involvement in the drug trade following the Autogolpe (self-coup) on 5 April 1992. On that day, Peruvian President Alberto Fujimori dissolved Congress, fired half of the judiciary, suspended the Constitution, and passed laws giving police broad powers to arrest and detain. In response to this action, USG economic and military assistance was suspended. The suspension resulted in the pullout of Special Forces trainers, but not D&M support (Ref. 81). Although SJ III was a military mission, it was considered outside the military assistance agreement.

The Autogolpe allegedly strengthened the links between military officers and drug traffickers, effectively "centralizing and corporatizing drug trafficking" (Ref. 80). Vladimiro Montesinos, a lawyer allegedly tied to traffickers, centralized control of counterdrug initiatives in the National Intelligence Service (SIN), the spy agency he

controlled, according to diplomats. As his powers increased, trafficking activity surged dramatically all over Peru. The commander of the U.S.-financed SLB complained that traffickers were receiving advance warning because the Peruvian Army insisted on clearing counterdrug operations in advance (Ref. 82).

The Embassy noted that military corruption has existed for a long time, and the Autogolpe did not provoke any significant increase. Around Tocache and Uchiza, army taxes ("cupos") ranging from $8,000 to $20,000 per trafficker plane had been in effect since before 1990. These planes carried at maximum 400 to 500 kilograms (Ref. 83; Ref. 84; Ref. 19, pp. 75, 162). One of the persistent reasons for corruption was the low wages paid to army officers – $250 a month for a general (Ref. 85).

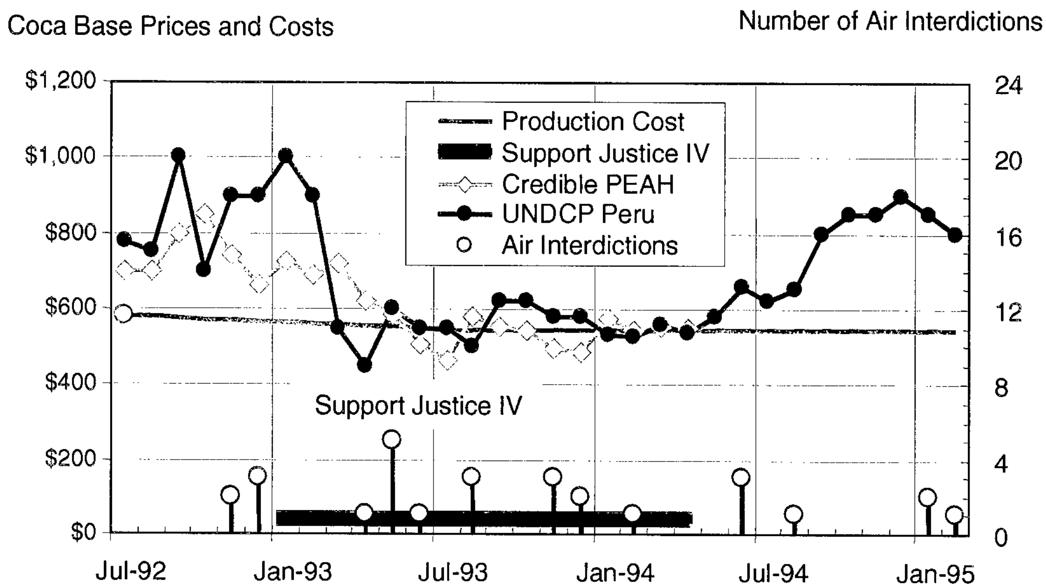
The capture of Abimael Guzman, leader of the Shining Path guerrillas, led to a rapid decline in the organization's strength and image. In September 1992, Guzman was arrested in Lima, Peru. That crucial event changed the view of the population about Sendero Luminoso and significantly reduced its strength (Ref. 40, p. 40). Some analysts have attributed the fall in coca prices in October 1992, to Guzman's capture because SL had been negotiating higher prices for coca growers since they gained control of the valley in July 1987. Since April 1990, SL guerrillas had instituted forced minimum prices – $320 for paste and $1,200 for base – to win the favor of coca growers (Ref. 34, p. 137; Ref. 19, p. 48; Ref. 84). The terrorists executed those who did not follow their set prices.

The reality is that SL terrorists attracted quite a bit of attention with their horrific acts but their press did not accurately represent their impact on the coca market. They did not "control 90 percent of the valley," as some have alleged (Ref. 53, p. 57). Rather, the Narcotics Affairs Section at the U.S. Embassy in Peru (NAS/Peru) described Sendero Luminoso's effect on the coca market at the height of its power to be as significant as soil conditions. The most significant impact of terrorism on the coca market, if any, was that their violence helped, along with counterdrug enforcement operations out of the SLB and the fungus outbreak, to disperse the coca business beyond the UHV.

3. Operation Support Justice IV

Operation SJ IV essentially continued D&M assistance where SJ III had left off. This operation was sustained for 17 months and resulted in more pronounced market effects. Figure III-7 shows the base prices in Peru along with the air interdiction events

and operational period for SJ IV. The associated chronology lists important collateral events of the period surrounding SJ IV.



1992

July 22: Pablo Escobar escapes.

Sept 12: Abimael Guzman is captured, and strength and image of SL deteriorates.

Nov: Operation Support Justice IV begins in Colombia.

1993

Jan 7: **Operation Support Justice IV** begins in Peru.

Sept: Steady State—USG decides to continue SJIV operations.

Dec 2: Pablo Escobar is killed.

Dec 15: USG terminates support for Santa Lucia Base.

1994

Feb: Demetrio Limonier Chavez-Penaherrera, "Vaticano," is arrested.

April: CNP begins aerial eradication of coca (INSCR March 1995, p. 84).

May 1- Dec 5: **Operation Support Justice IV** ends—USG suspends sharing of real-time aircraft tracking information with Colombia and Peru, due to USG legal liability dispute over lethal interdiction.

Figure III-7. Coca Prices and Costs Surrounding Operation Support Justice IV

a. Sequence of Events

In September 1992, U.S. SOUTHCOM and Peruvian Air Force officials reached an agreement to prevent the C-130 incident from happening again. In November, SJ IV operations began in Colombia. Following the successful Constituent Congress elections in November 1992 and the Christmas break, SJ IV officially began in Peru on 7 January 1993 (Ref. 86, p. 4; Ref. 75). From 7 January to 13, July FAP fighters reportedly

intercepted 209 suspect trafficker aircraft over the UHV, 30 of which were shot down or destroyed on the ground (Ref. 61, 1994, p. 15).[3]

In mid-February 1994, the Government of Colombia announced a policy where the Colombian air force would force down suspect trafficker aircraft. The established rules of engagement stated that under very specific circumstances, private aircraft operating in Colombian airspace that failed to heed orders to land may be shot down (Ref. 61, 1994, p. 19). U.S. DoD officials, in the wake of the accidental shooting down of two American helicopters over Iraq in April 1993, had reviewed cases of accidental shoot-downs for possible liability and found issue with the shooting of suspected trafficker planes in flight. International Civil Aviation Association treaties ban all attacks on civilian aircraft.

On 1 May 1994, DoD officials suspended sharing of real-time aircraft tracking information with Colombian and Peruvian officials, from concerns that U.S. officials could be held legally liable if U.S. data were used by these countries to shoot down civilian aircraft. On 26 May 1994, the U.S. Department of Justice advised all relevant agencies that assistance programs directly or materially supportive of shoot-downs should be suspended pending the completion of a thorough review of the legal questions. U.S. embassy officials estimated civilian aircraft to be involved in almost 90 percent of drug-trafficking activities in Peru (Ref. 87).

b. Market Effects

Coca base prices in early 1993 were observed to be an all-time high (Ref. 80). SJ IV assistance helped the Colombian Air Force detect 600 trafficker flights, compared to 250 flights detected the year before without USG support (Ref. 88). By April 1993, the U.S. Embassy in Peru had observed a visible reduction of trafficking flights, and by July 1993, steadily decreasing coca prices. Coca growers complained that prices were low because "the planes were not landing" (Ref. 89).

By March 1994, the U.S. Embassy in Peru had observed a shift in previously established air patterns of air export of base from Peru to Colombia. Prior to mid-1993, most aircraft moving drugs departed from central or northern Peru in the Huallaga or Ucayali River valleys. By the end of 1993, there was clear evidence of movement of

---

3 These large numbers of interceptions, shoot-downs, and destruction far exceed the verified numbers from NAS shown in Figure III-7. It is likely that intelligence had multiple counts that were not properly fused. Note that reports agree during 1955 in the early FD/SD period.

base in smaller quantities by air taxis or other means from production areas further north to locations in far southeastern Peru. From there, the product was consolidated into larger loads (approximately 1,000 kilograms) to await pickup by twin-engine, longer-range aircraft for movement, often through Brazilian airspace, to Colombia.

Before the May decision to stand down, traffickers minimized their exposure to the air interdiction threat. They used fewer flights with larger loads, flew mainly in the early evening hours using indirect routes, and spent on average only 10 to 12 minutes loading and unloading their cargoes. After the May decision, traffickers began to fly more flights, load smaller amounts, fly during the day, and increase their time on the ground to 20 to 25 minutes.[4] In one area, the traffickers' aircraft sometimes remained overnight. The traffickers reverted to routes that are more direct in the absence of radar assistance (Ref. 87). By 1994, coca prices were increasing, and many farmers were expanding their coca plots (Ref. 40, p. 41). Figure III-7 shows that UNDCP base prices rose from around $600 per kilogram to well over $800 by November of 1994.

c. Changes within the Illicit Coca Business

Coca growers continued to vertically integrate their processing in response to low coca derivative prices caused by interdiction and targeted enforcement operations. Peruvian National Police (PNP) operations reduced the number of large-scale coca base laboratories in the jungle within helicopter range of the SLB. There was a shift to numerous smaller labs in outlying jungle and urban areas, which began with PNP Condor operations from 1985 to 1986, and continued with DEA Snowcap-assisted operations, which began March 1987 and continued through the mid-1990s (Ref. 90; Ref. 75). These operations affected prices locally. One effect, observed in several towns in 1988, was a price decrease for leaf but increase for paste and base, reflecting the loss of processing labs (Ref. 91). Another observed effect was increased price differences between municipalities. The town of Saposoa, for example, was the center of large DEA operations in June 1993. During that month, Saposoa's prices were among the lowest in the valley (Ref. 89).

---

4 These comments conflict with the verified data of Chapter IV, Table IV-10, which show that loads were larger in post-SJ IV rather than smaller. Since detailed intelligence was weak during this period without USG support, we suspect Table IV-10 is incomplete.

4. Resumption of USG D&M Support and Implementation of the Force-Down/Shoot-Down Policy

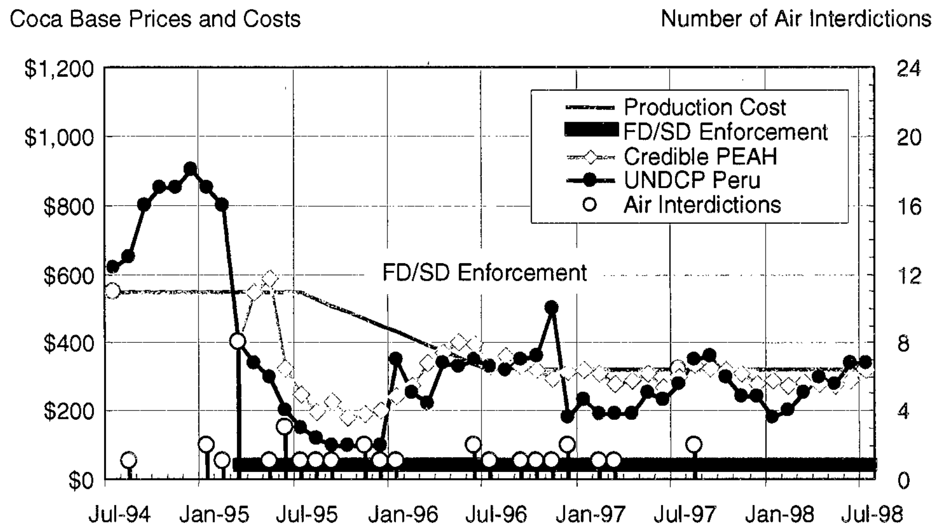
The resumption of USG D&M support with an accepted procedure for shoot-downs resulted in the longest sustained price drop below cost to date. Figure III-8 shows the sudden drop in Peruvian coca base prices reported by UNDCP followed by only modest recovery in 1996 and thereafter. The associated chronology of events shows that only the December 1996 – January 1997 raids on Colombian cocaine laboratory complexes correlated with another sudden price drop and subsequent slow recovery. The most important change from implementing the shoot-down policy was the change in the rules of engagement, which had the net effect of significantly increasing the effectiveness of the operations, without significant increase in interdiction force size.

a. Force-Down/Shoot-Down Process

Trafficker interdiction follows a standard procedure. USG radar-equipped aircraft detect flights between Peru and Colombia and share the tracks of suspected trafficker planes flying without a flight plan in a no-fly zone. Most of the Colombian and Peruvian airspace east of the Andes is a no-fly zone, especially after dark. Once a suspected trafficker plane is detected, within 2 to 3 minutes a tracker jet and two Peruvian fighters scramble to intercept the flight. The tracker follows the trafficker at a distance of roughly 3 miles and radios Peruvian or Colombian jets (which have no radars) to the trafficker. Peruvian and Colombian fighters, under International Civil Aviation Organization standards for intercepting aircraft, attempt to contact by radio and visually signal the pilot, such as by rocking their wings and giving standard visual signals. The plane is asked to follow the jet to a landing strip. If the trafficker plane ignores the interceptor's request, a high-ranking air force officer of Peru or Colombia can give a "kill order" and the interceptor will fire warning shots. Colombian interceptors follow the plane and wait until the suspected drug flight has landed and passengers have fled before strafing the plane. In Peru, interceptors open fire with .30 caliber machine guns and shoot the plane out of the air (Ref. 92; Ref. 93; Ref. 75).

b. Sequence of Events

USG officials worked quickly to resume the sharing of D&M intelligence. Congress approved legislation in August 1994 and the President signed a determination in December allowing the resumption of sharing with countries where trafficking presents a national security threat (Ref. 61, 1994, p. 15). Peru and Colombia were given this determination and D&M support continued in January.



1994

Dec: Presidential Finding approves USG support to lethal air interdiction or civilian aircraft after appropriate warning –shoot-down policy approval.

1995

January: USG D&M support resumes in Colombia.

Jan 26-Feb 28: Peru is engaged in a border war with Ecuador.

March: **USG D&M support** resumes in Peru. A record 8 aircraft are interdicted

April: Trafficker flights decline: 55 planes/month in February to 5 planes/month in April (NAS/Peru July 1996)

June 9: Gilberto Rodriguez-Orejuela, of Cali Cartel, is arrested. (Price already declined)

June 5: Abelardo Cachique-Rivera, one of the largest Peruvian base traffickers, is arrested.

August 6: Miguel Rodriguez-Orejuela, of Cali Cartel, is arrested.

July 4: Jose Santacruz Londono, of Cali Cartel, is arrested.

December: USG temporarily stands down D&M support.

1996

March 5: Jose Santacruz Londono, of Cali Cartel, killed

April: USG support has resumed as Operation Laser Strike

May: In Guaviare and Caqueta, Colombian army bans sale of cement and gasoline, materials used predominantly in those areas to process cocaine. Army also destroys 64 drug labs and ten airstrips in the area

Dec 6: CNP begins major raids on Colombian cocaine laboratory complex.

1997

January: CNP complete major raids on Colombian cocaine laboratory complex.

1998

September: Bolivian bound potassium permanganate interdicted and base quality plummets.

Figure III-8. Coca Base Price and Cost Before and During FD/SD Period of Operations

Just as the operations were beginning, on January 26 a border war began between Peru and Ecuador. At the Government of Peru's request, over-flights by AWACS were suspended. The USG suspended ground-based radars in Peru and Ecuador as well. Several Peruvian Army checkpoints and bases in Huallaga Valley were effectively abandoned as the Peruvian military redeployed to the border area. FAP planes were also deployed to support the border conflict and were not available as interceptors in CD

interdiction activities. The war was over by 28 February. During mid-March 1995, USG sharing of real-time trafficker tracking data resumed in Peru. By the end of 1995, more than 23 trafficker aircraft had been forced down, seized, and/or destroyed in Peru (Ref. 57, 1996, p. 101). USG radar support was dubbed operation "Green Clover" until April 1996 when the name changed to "Operation Laser Strike" (Ref. 94).

The D&M support stood down in December of 1995, and 22 trafficker flights were recorded that month, while there had been six or fewer for the previous 3 months. Operations resumed early next year, but there were significantly more flights for the following 7 months. Since then, D&M support and air interdiction operations continued until the time of this report, and confirmed detected flights have diminished to an average of fewer than four per month. Although traffickers have become more sophisticated and diverse in their operations, the aggregate traffic over the air-bridge is still suppressed to an insignificant level as river transportation and diversion to other markets are believed to carry the residual Peruvian coca production.[5]

c. Market Effects

Figure III-8 shows that prices may have begun to decline even during the Colombian phase of resumption of air interdiction, that is, January and February 1995. Three interdictions were also accomplished during these 2 months. However, the small fall-off of base prices in those 2 months could just as well be a statistical fluctuation of the price data collection process.

Estimated trafficker flights in 1995 were half of those in 1994, and significant coca price drops were observed by several sources as early as April 1995 (Ref. 57, 1996, p. 102; Ref. 95; Ref. 96). Beginning in June and July 1995, 33 to 50 percent of growers stopped harvesting. Some areas had ceased to receive even maintenance care and appeared to be at least temporarily abandoned (Ref. 57, 1996, p. 102).[6] In November 1995, the Embassy reported coca grower pleas for alternative development assistance. In January 1996, development agency community surveys yielded evidence of food scarcity and acute malnutrition in the Apurimac Valley. These conditions were directly linked to the drastic fall of coca prices during 1995 (Ref. 97).

---

5 Interviews with U.S. Embassy staff in Peru, 1999.

6 Interview with Directors at NAS, U.S. Embassy, Peru, July 1996.

Traffickers adapted quickly. Previously, the most frequently used airstrips were in the Huallaga Valley (Ref. 61, 1993, p. 16). After the shoot-downs, many drug traffickers were moving paste and base via land and river or through short air hops to Colombia, often through Brazil. Since Brazil has no radars, their airspace is uncontrolled (Ref. 98, p. 3). One common route was a day's journey on any of several Amazon tributaries to Iquitos on the Amazon River. From there, base could be transported to the northern Putumayo region or Leticia, Colombia. These areas are very close to the border, meaning less flying time. By June 1996, DEA officials observed rebounding prices (Ref. 99). The price for base at the border increased faster than the price in the UHV, by October 1996 reaching $1,000, compared to $300 in the UHV (Ref. 100).

The Embassy reported in January 1996 that the price of base increased as it got closer to the border. Air interdiction made it expensive and difficult to move by air, and transporting large amounts of base successfully by land remained problematic. There was an observed reduced quality in recently seized base, which resulted from long storage as traffickers awaited a transportation opportunity. The shelf life of base is approximately 6 to 8 months, but the cocaine alkaloid breaks down faster when stored in jungle humidity.

The interdiction effort had a significant impact on coca cultivation and processing in Peru. From 1995 to 1996, cultivation in Peru decreased somewhat, but increased in Colombia by 32 percent (Ref. 32). Very likely, Colombian traffickers recognized the vulnerability of the air-bridge to Peru and began investing in new cultivation as early as 1994. Even with the increase in Colombian cultivation, however, there was an overall reduction in potential cocaine production. The U.S. Embassy in Peru observed increased, but small, production of HCl transported directly form Peru to Mexico, bypassing Colombia (Ref. 57, 1997, p. 105). Air interdiction operations continued to enforce the shoot-down policy over the next few years, and by 1999, coca cultivation in Peru had declined 66 percent from pre-shoot-down periods (Ref. 5, Colombia, 1999) while Colombian cultivation continues to expand to replace these losses.

d. Subsequent Events

After this in depth review of events in Peru terminated, one subsequent major operation and new developments in Peru warrant mention.

During December of 1996 and January of 1997, the Colombian National Police (CNP) carried out a series of raids on major laboratories in the Mira Flores area of the Guavaire. The CNP reported one complex to have 7 metric tons of cocaine, 1.5 metric

tons of base, and 375,000 gallons of liquid chemicals on site when attacked and destroyed. They also reported evidence for FARC involvement in this complex's operation. The entire complex was estimated to be capable of refining more than 100 metric tons of cocaine per month. Although this is a peak capacity, it is likely that production was highly variable with harvests and demand variations. Nevertheless, this complex could support one-third of the entire production supplying the transit-zone traffic to the United States. Simultaneous with these laboratory attacks, the U.S. conducted operation Frontier Shield to disrupt go-fast traffic in the eastern Caribbean (Ref. 16).

More recently in 1999, during our trips to the Embassy in Peru, we learned of several important events. Base prices have recently increased to more than $500 per kilogram; at this level, the DEA reports seeing evidence of leaf harvesting from abandoned coca bushes already overgrown by shrubs and small trees. This suggests that a combination of markets have emerged to support the current level of illicit coca production. Sources in the U.S. Embassy in Peru see these markets as some leakage to Colombia whether by river to the Peruvian border or by private planes filing flight plans with full knowledge that the Peruvian Government lacks resources to trace flights and inspect most planes. Other leakage is to Bolivia or the Brazilian connections of the former Bolivian cocaine trade to Europe. Since Bolivian cocaine quality diminished as a result of successful interdiction of precursor chemicals and decline of public support for illicit coca growers, Peruvian cocaine probably has been replacing Bolivian cocaine going to Europe. Finally, large seizures of laboratories and cocaine ready for shipment from Pacific Coast ports indicate a growing direct trade with Europe and possibly Mexico.

D. OBSERVATIONS ON OTHER CONTRIBUTING FACTORS

Several factors contributed to the success of the air interdictions against the air-bridge traffic to Colombia as well as the subsequent movement toward a reduction in lawlessness in Peru.

- The Peruvian Government strongly supported the counterdrug efforts, placing it second only to fighting the insurgency movements; however, President Fujimori demanded there be alternative development aid as well as military assistance from the USG. It is likely that fear of the insurgents by the local populations contributed to gaining the information necessary to capture their leader and diminish their influence thereby increasing security in the countryside.

- DEA operations in conjunction with PNP provide valuable information about how the illicit coca business functions, which informs the process of planning air interdictions and interpreting economic data.
- The "Fujimori Doctrine" of attacking the traffickers and not the coca farmers reduced general hostility toward the central government of Peru. For example, eradication became a more voluntary program in conjunction with alternative development.
- United Nations and USAID alternative development programs were able to collect useful time series of illicit coca prices that formed a basis for evaluating economic impact of interdiction operations.
- Alternative development programs further improve police presence, security, and support from a population formerly threatened by violence from insurrection and traffickers.

Understanding of the interdiction process and use of market information to resolve the interdictor's dilemma enabled leaders of operations to argue effectively for continuation even as trafficking declined. We have learned to expect an anti-correlation between low base prices in the markets isolated by interdiction, where there is a glut, and high coca prices beyond, where shortages develop.

This anti-correlation of base prices (increasing interdiction rates and *decreasing* base prices) with successful operations strongly refutes the taxation assumption of the 1980s research. All of those 1980 economic models have base prices increasing with increasing interdiction rates – thus the taxation assumption. Equilibrium economics is fundamentally inadequate for modeling interdiction operations.

Modest pressure applied to the air-bridge to Colombia caused a major collapse in Peru and forced Colombians to plant their own coca to replace their lost access to Peru's cultivation. The Peruvian Air Force had only two fighter interceptors to engage the air-bridge, but interdicting only a few percent of the flights with a lethal threat caused more than an 80 percent drop in traffic.

In response, Colombian producers had to replant virtually the entire coca crop within more secure regions of Colombia – more than 56,000 hectares between 1994 and 1998 and still increasing. At more than $2,500 per hectare, this is $140 million of capital investment that will take several years to recover. Even this investment does not reduce the coca producers' dependence on air transportation. Since coca production is even more geographically concentrated now than before, the stage is set for another operation against the Colombian traffickers' air transport.

CHAPTER IV

DETERRENCE OF TRAFFICKERS

IV. DETERRENCE OF TRAFFICKERS

Chapter III explained that the interdiction of a small fraction of the air traffickers flying coca base from Peru to Colombia led to the collapse of the Peruvian illicit coca market. Key to this successful severing of the air bridge was the threat of potentially lethal consequences of interdiction by Peruvian fighter planes. While trafficker organizations are generally willing to lose 30 percent on average of their loads to interdiction, the air trafficking pilots are not willing to take more than a small percent risk of potentially lethal consequences of interdiction. In this chapter, we quantitatively analyze and model the psychology of the air traffickers confronting the interdiction threat to determine the percent who are deterred from trafficking for various probabilities and consequence of being interdicted. We employ interview data obtained from incarcerated smugglers, the theory of risk perception, and the data from the operational phases against the air bridge to determine the form of the mathematical model of deterrence and to calibrate it against the Peruvian experience for various levels of interdiction threat.

Having gained this understanding of deterrence, we address questions such as the following:

- Why do traffickers ignore an insufficient level of interdiction risk?
- For various consequences of being interdicted, what probability of interdiction is necessary to make 80 percent or more of the traffickers quit?
- How can a relatively modest deterrence force choke off the great majority of an illicit trade – disproportionately damaging the cocaine business rather than simply imposing a proportionate "tax" on illicit activity?
- Why can traffickers not readily buy their way around the chokehold of deterrence against the air bridge?

These findings should be applicable to ongoing counterdrug operations against drug transportation in Colombia, Bolivia, and elsewhere.

A. THE DETERRENCE PROCESS

Military planners realize that opposing air forces cannot sustain even modest attrition rates of a small percent for a prolonged campaign. Although interviews with incarcerated smugglers show that owners of drugs are willing to sustain much higher loss

rates, the smugglers themselves are not willing to face capture or incarceration at this rate.[1] During these interviews, some smugglers admitted that the risks attracted them to smuggling; however, if they had realized the true risks of being caught and the severity of the penalties, they claimed they would have thought differently. Nevertheless, we can conclude that, for a low level of risk of interdiction, traffickers either are attracted to smuggling or ignore the risks. This is the first indication that there is a threshold of risk of interdiction – a point below which there is no deterrence and above which increasing numbers of smugglers no longer are willing to take the risks and quit. This deterrence threshold depends, of course, upon the severity of the consequences. Although the willingness to smuggle also depends upon the financial rewards offered by traffickers, we will develop the basic deterrence model under the assumption that smugglers are amply rewarded. After developing the basic deterrence model, we will address the relationship between greater wages for taking greater risks. Once we have a general mathematical expression for the deterrence model derived from interview data, we will use other research findings and data from Peruvian and other operations to further validate and calibrate the model.

1. Conceptual Model of Deterring Smugglers

Smuggling success depends upon both the willingness to attempt to smuggle and, if attempted, the ability to avoid interdiction. Conceptually, the probability of smugglers being thwarted, P_t, i.e., being interdicted or deterred, can be expressed mathematically as follows:

$$P_t = 1 - (1 - P_I) \cdot W(P_I) \qquad (1)$$

Here, P_I is the probability of being interdicted assuming a smuggling attempt is made; $W(P_I)$ is the probability that smugglers would be *willing* to attempt to smuggle given their perceived probability of interdiction, P_I, and the severity of the consequences of interdiction. The right side of equation (1) is easily interpreted if read from right to left: of the fraction, $W(P_I)$, willing to smuggle, some of these, $1 - P_I$, are successful; therefore, 1.0 minus the successful fraction is the *unsuccessful* fraction.

Equation (1) assumes that smugglers' perceptions of the probability of interdiction are equal to (or at least proportional to) the actual probability of interdiction. If information was slow to reach most of the smugglers or they were slow to adjust their

---

1 See Appendix A on the deterrence model.

activities based on new information, real risks might differ from perceived risks or behavior. For example, during the early months of U.S. support to the Peruvian force-down, shoot-down policy, pilots may not have either believed interdiction forces would be as effective as they were or only slowly learned the true risk of interdiction. Since we can adjust equation (1) later for lags in perception by observing smuggler responses to real operations, we initially assume the simpler form of the equation.

2. The Psychology of the Willingness to Smuggle

The U.S. Customs Service sponsored a consulting research group within Rockwell International (Ref. 10) to interview confidentially 112 former drug smugglers incarcerated in Federal Prisons. The former smugglers were asked questions concerning the conditions under which they would be willing to continue various illicit activities. Although interview data are opinions of smugglers, such *opinions* are the ultimate basis for deterrence. These interview results were remarkably useful – determining the mathematical form of the function $W(P_I)$ and initially calibrating its coefficients as a model for the willingness to attempt to smuggle against various chances and consequences of failure. The interviews also explored other factors influencing a smuggler's behavior such as the effectiveness of compensation to offset risks.

Appendix A to this report explains how we derived the unknown function, $W(P_I)$, from the interview data.

$$W(P_I) = \left(\frac{P_I}{P_{\min}}\right)^{-1.03\pm0.07} \qquad \text{for } P_I \geq P_{\min}$$

$$= 1.0 \qquad \text{for } P_I \leq P_{\min}$$

Here, the parameter, $P_{\min}$, represents the threshold probability of interdiction at which smugglers begin to be deterred. At probabilities of deterrence less than $P_{\min}$, smugglers ignore the risks. Since $P_{\min}$ depends on the consequences of interdiction, increasing the severity of the consequences for the same level of interdiction risk can deter some smugglers, who ignored the interdiction risks with less severe consequences.

Figure IV-1 shows the willingness function, $W(P_I)$, overlaid with smuggler interview data from four of six cases of different interdiction consequences. Here, the smuggler data are cumulative fractions willing to smuggle at risks less than or equal to the indicated probability of interdiction. In the interviews, smugglers were asked whether they would personally, designated *self*, continue against various interdiction odds. They

were also asked to imagine a former *associate* and to answer the questions as if they were that person. For all cases, the inmates on average imagined their former associates to be less deterred than themselves. Some inmates volunteered that they had underestimated the likelihood and consequences of being caught, and it is likely that they answered for their "associates" on this basis.

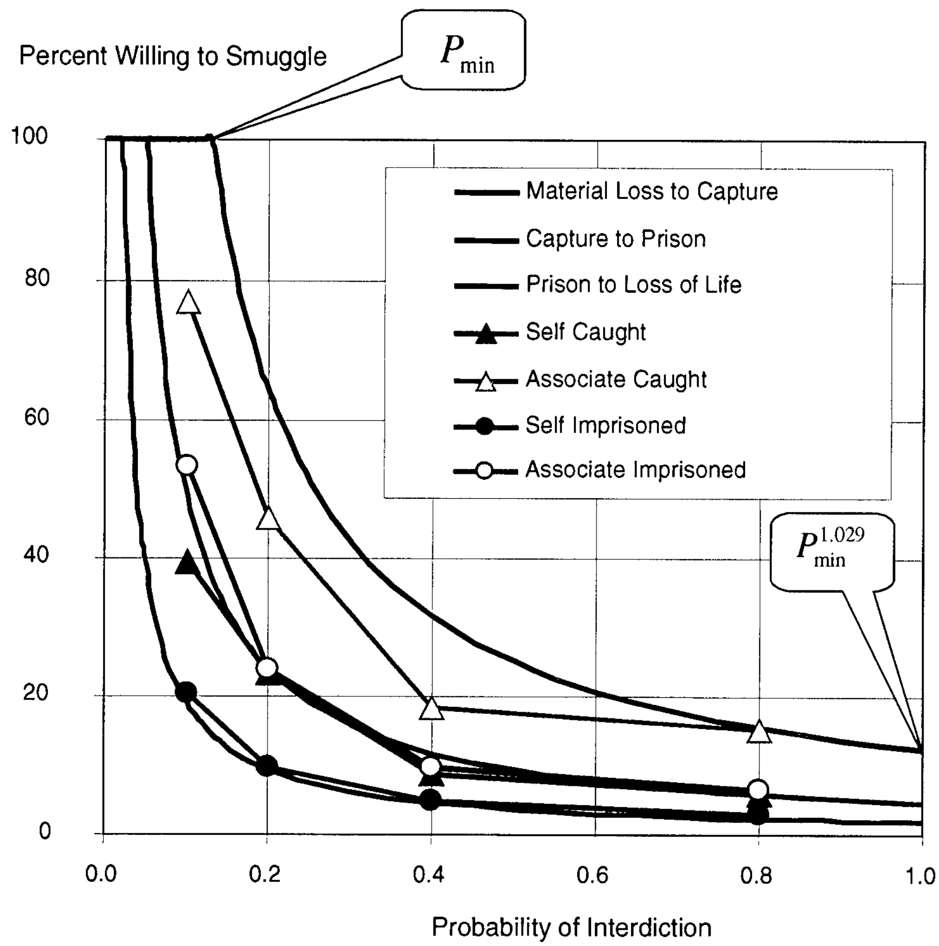


Figure IV-1. Willingness to Smuggle Model with Representative Data

Although the exponent of -1.03 ± 0.07 in $W(P_I)$ is consistent with being -1.0, we preserve this small difference because it shows the uncertainty bounds on the exponent and reveals any sensitivity the model may have to deviations from -1.0. Because the model is consistent with a simple reciprocal, which is an exponent of –1.0, it may represent a more general law of human behavior than just avoiding the consequences of being caught smuggling. For example, Appendix A gives data from the early days of automobile use in the United States that logically represents a voluntary activity of high risk embraced by a very small fraction of the population. In 1900, the risk of death

during an 8 hour trip was 0.5 percent; certainly, this was an "extreme sport." From 1900 to 1910, the fraction willing to drive increased in proportion to decreasing fatality rate per hour of driving, the same mathematical form as our willingness function. By 1910, nearly one percent were driving and risks had dropped 50-fold but, thereafter, up to 1930, the percentage of Americans willing to drive increased more rapidly than the risks fell. Thus, the early data may represent an experimental, "sport" phase of automobile use while later years represent adoption for more practical and necessary purposes and a drift away from the willingness function.

The thresholds for various values of P_{min} are clearly visible along the upper border, which represents 100 percent willingness to smuggle. There are also residual fractions, $P_{min}^{1.03}$, of the smugglers, who are willing to smuggle *knowing* they would be interdicted. Some of the inmates even volunteered this during their interviews; for example, some said they could earn more for their families by one smuggling attempt than they could earn for the entire period they would spend in jail. Because our interest here is to represent classes of smuggler behavior, we show P_{min} values and boundaries defining those ranges in Figure IV-1. Appendix A gives the exact P_{min} values that fit the six distinct interview cases. All three cases for smuggler themselves fall in the first range from P_{min} of 2 to 5 percent. The three cases for "associate" fall in a range of P_{min} values between 5 and 8 percent. For owners losing loads because smugglers abandon them to escape, there is another threshold at approximately 30 percent. Now note that the thresholds appear to form a geometric progression with scale factor of 2.5:

2 x 2.5 = 5

5 x 2.5 = 12.5

12.5 x 2.5 = 31.25

therefore, we chose boundaries at 2, 5, 13, and 30 percent as the framework for the deterrence model.

Knowing the function representing the willingness to smuggle enables us to give a specific form to the deterrence model:

$$P_t = 1 - (1 - P_I) \cdot \left(\frac{P_I}{P_{min}} \right)^{-1.03 \pm 0.07} \qquad (2)$$

where P_{min} depends upon the trafficker's perception of the consequences of being interdicted—*the more severe the consequences, the smaller the value of* P_{min} *necessary to deter some traffickers.* For all $P_I \leq P_{min}$, $P_d = 1.00$, therefore, P_{min} also defines a *non-*

linear break point transition between no deterrence, $P_I \leq P_{\min}$, and onset of deterrence, $P_I \geq P_{\min}$.

Figure IV-2 shows this full deterrence model along with the representative interview data and boundaries from Figure IV-1.

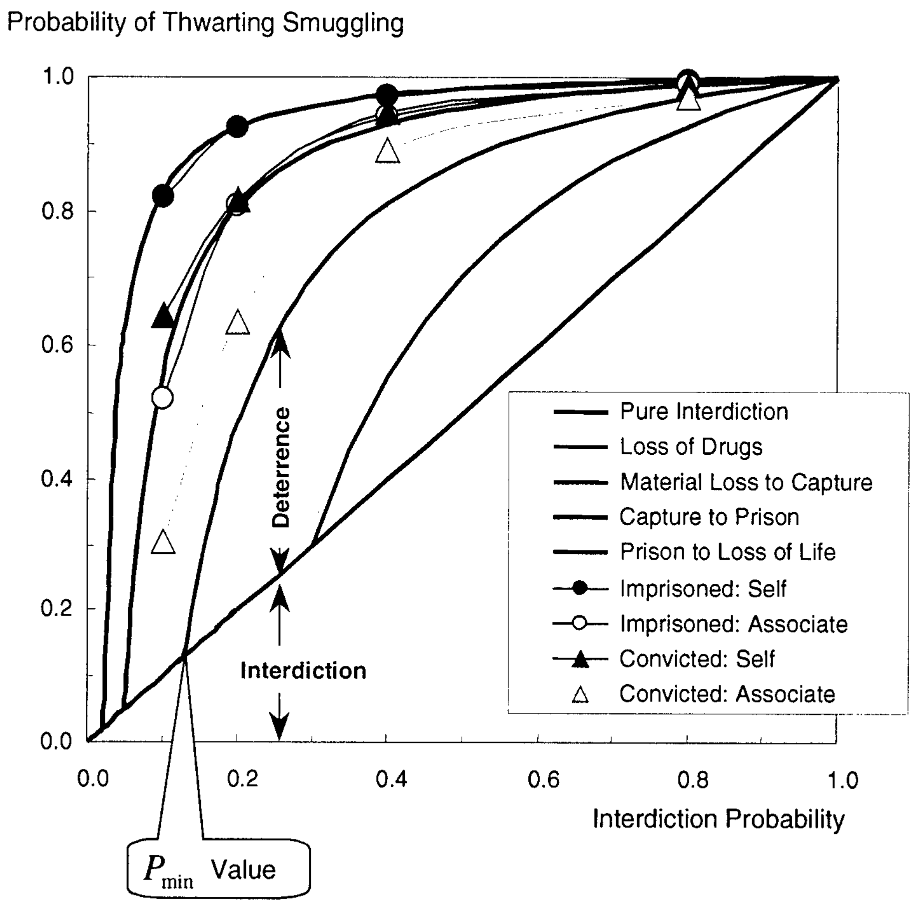


Figure IV-2. Deterrence Model Showing Representative Trafficker Interview Responses

3. Willingness to Change Location or Methods, or Quit

Interview respondents were asked whether they would change their location of smuggling for given risk levels. These response patterns yield the same thresholds as for quitting, 2 percent for "self" and 5 percent for "associate." Asked how many loads they would have to lose before stopping or changing methods of smuggling, on average the answers ranged between 2.2 and 3.7 loads depending upon the conditions. However, this pattern of responses, shown in Appendix A, followed a different mathematical function, a decaying exponential. Therefore, the inverse power function for $W(P_I)$ is not the only distribution that can result from the interview process, and the close fit to both very

different functions attests to the degree of precision one can obtain from these interview data. Finally, the respondents said that if they were the owners of the drugs but did not smuggle themselves, they would be willing to lose an average of 31 percent of their loads before quitting while their associate would be willing to lose 43 percent.[2] This is the other "range" of thresholds representing a different class of consequences – a $P_{\min}$ slightly greater than 30 percent representing the loss of drugs alone. For more details on all these cases, see Appendix A.

4. Calibrating the Model with Data from Air Interdiction in Peru

To calibrate our model against data from air interdiction operations attacking the air bridge from Peru to Colombia requires us to compute P_I and $P_t^{\prime}$ for each major operational period. With such independent estimates, we could compare them to the form of the model in Figure IV-2 to determine whether they match with a common interpretation.

To estimate P_I and P_t from operational data requires several time series from Peru and the air interdiction operations. Fortunately, these data were collected by the Narcotics Affairs Section (NAS), the Tactical Analysis Team (TAT) of the U.S. Embassy in Peru, and the Crime and Narcotics Center (CNC) at the Central Intelligence Agency.

Two data sets from the NAS provide a measure of the probability of interdiction, P_I. Verified interdictions of flights over the air bridge divided by verified trafficker flights over the air bridge forms a ratio that estimates P_I. Two other data sets provide a measure of the probability of interdicting or deterring traffickers, P_t. The metric tons of base that were detected being transported over the air bridge, provided by the TAT, divided by the metric tons of coca base potentially produced in Peru for transport over the air bridge, provided by the CNC, forms a ratio that estimates the *successful* trafficker transport, $1-P_t$, from which it is easy to compute P_t.

Of course, we must make several adjustments to the raw observational data to obtain meaningful ratios and to estimate their associated uncertainties. These adjustments include the undetected flights, scaling for the purity of the base being flown

---

2 These 31 and 42 percent levels are simple averages of the raw data. By fitting to an exponential distribution, we get instead 22 and 35 percent. Therefore, we adopt 30 percent as a representative overall average. Note that these exponentials are weak fits, while the willingness functions are still weaker fits to these data.

to Colombia relative to that of the potential cocaine, and estimating the fraction of potential production consumed internally or transported by other means.

5. Method of Adjustment for the Sources of Uncertainty

The next two sections, B and C, become quite involved because they analyze more than 20 sources of uncertainty. Before we begin examining each uncertainty in detail, it is important to understand the overall purpose and method behind this analysis. Its purpose is to identify every plausible source of uncertainty and show that these are reasonably understood, bounded, and consistent among themselves. The method is more complex.

We begin by showing that the small number of interdictions requires us to group these data into operational periods to obtain stable estimates of interdiction rate, P_I. We next show that the expected statistical fluctuations on these small counts are still larger than the variations due to the combined sources of uncertainty for P_I; thus, the adjustments on P_I shift the interdiction rate less than the range of these statistical fluctuations. In this analysis of P_I we learn two operational lessons: that during SJ IV some months had many more smuggler flights than others, and that the number of interdictions per month remarkably remains essentially the same before and after the implementation of the shoot-down policy.

To estimate P_t, we need to understand and estimate the adjustments and variations on the potential tons and smuggled tons of coca base. The best opportunity to do this is during SJ IV because the extensive intelligence and D&M support during this operation provided the best quality data. We also believe from anecdotal evidence and the large volume detected crossing the air bridge that essentially all of the potential base available was flown. Independently, we estimate an upper bound on the plausible amount of coca base that might have flown that was unaccounted for and, from this, we estimate plausible bounds on the number of flights not detected and those identified as smuggler flights that were later aborted and flown again.

This is important because the strongest evidence for the impact of deterrence following the implementation of the shoot-down policy is the comparison of SJ IV with the first two years after the implementation of the shoot-down policy. Because both time intervals enjoyed extensive intelligence and D&M support, we have a high level of confidence that most of the tons transported over the air bridge were detected. Therefore we conclude that the sharp drop in tons carried over the air bridge had to be real.

In estimating all of these adjustments and their associated variability, we reviewed both consistent and inconsistent reports and interview comments about the sources of uncertainty. From this, we make crude estimates based on the plausible upper limits to the variability and make adjustments central within these ranges. For some sources of uncertainty, we use counting statistical fluctuations of numbers of flights as an estimator for variability. After all of these adjustments and variability estimates have been combined, we also examine the consistency of the overall variability with the degree of variability among operational periods. This reveals that we have *overestimated* the variability of these data, which gives us more confidence that we have directly or indirectly captured all of the sources of uncertainty. Finally, the known adjustments easily account for the difference between the raw data on tons carried over the air bridge and total potential tons produced. Again, there is not much room for significant uncertainties to go undetected or affect our conclusions about deterrence. Overall, these methods employed in Sections C and D are very approximate, combining many judgments and conservative bounds on uncertainty. The calculations are not intended to be precise estimates, but rather crude means of limiting uncertainty to gain confidence that we understand the differences between our best estimates and the raw data.

After comparing both the raw data and our best estimates for the operations against the air bridge with the deterrence model in Section D.1, we will examine the sensitivity of our model parameters to the adjustments and combined variability of these data in Section D.2. Here, we will see that the largest uncertainties do not much affect the estimate of $P_{\min}$ for each operational period, and we will also glean some operational lessons from this sensitivity analysis.

B. FLIGHTS, INTERDICTIONS, AND OPERATIONAL PERIODS

Near the end of this section, we calculate the probability of interdiction, which is the same as the interdiction rate. The raw data for this calculation are the detected flights per month and the verified interdictions per month as shown in Figure IV-3. Note that the scale for flights per month is ten times the scale for interdictions. Also note the abrupt transition following the eight interdictions in March of 1995. This was the first month with full FAP engagement of the traffickers implementing the force-down, shoot-down (FD/SD) policy with USG D&M support. Trafficker flights dropped abruptly from an approximate average of 40 per month to an average of fewer than 10 per month. Even the minimum numbers of flights per month in the last 3 years before the policy was enforced were larger than the maximum numbers of flights soon afterward. Such is the

deterrent effect of the FD/SD policy combined with modestly effective air interdiction campaign.

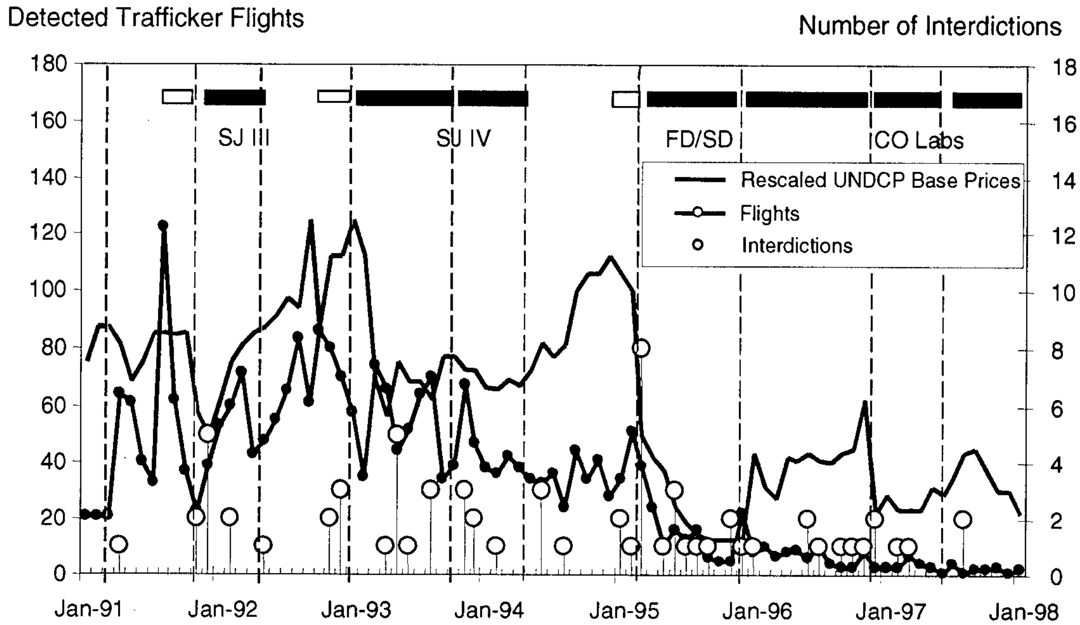


Figure IV-3. Detected Trafficker Flights over the Air Bridge and Verified Interdictions

Also shown in the background for comparison purposes is the UNDCP price series for coca base in Peru plotted on an arbitrarily chosen scale of $1,000 equals 120 on the flights axis. The abrupt drop in prices along with the drop in air bridge traffic proves that the designated interdiction operations effectively damaged the illicit coca business in Peru and severed the bridge in March 1995. The large drop in base prices provided the concrete evidence necessary to sustain the interdiction effort even though the number of flights had fallen drastically.

We will explain the source of these data after explaining the need to group them into operational periods.

1. Operational Periods

Since an empirical estimate of the probability of interdiction is the ratio of interdictions to flights and since both these numbers can be quite small on a monthly basis, a time series of these monthly ratios would fluctuate wildly. This alone would justify grouping several months of similar interdiction conditions into "operational periods." To complicate matters somewhat, Figure IV-3 shows that the numbers of flights per month during SJ IV appear to form several pulses; thus, we must be careful in

choosing the months at which to separate periods. After explaining why these pulses were not simply random fluctuations, we group the traffic and interdiction data into operational periods with boundaries at operationally significant transition points and with durations of 6 to 12 months.

a. Traffic Pulses

To reject the hypothesis that these "pulses" were random fluctuations, we created a baseline smooth trend hypothesis, which followed the data quite closely. Since a 7-month triangular sliding average is highly correlated with the data, it should give a smaller chi-square deviation than alternative models. Figure IV-4 shows the flights per month with the sliding average superimposed. It also shows the range of plus and minus two standard errors, about the 95 percent confidence limits. If the deviations from the sliding average were purely counting statistical fluctuations, the chi square for the 16 months of SJ IV would be 42. Even for 16 degrees of freedom, the probability of this at random is 0.0004. Alternatively, the chances of having 5 excursions beyond the 95 percent confidence bounds in a sample of 16 events is less than 0.001.[3]

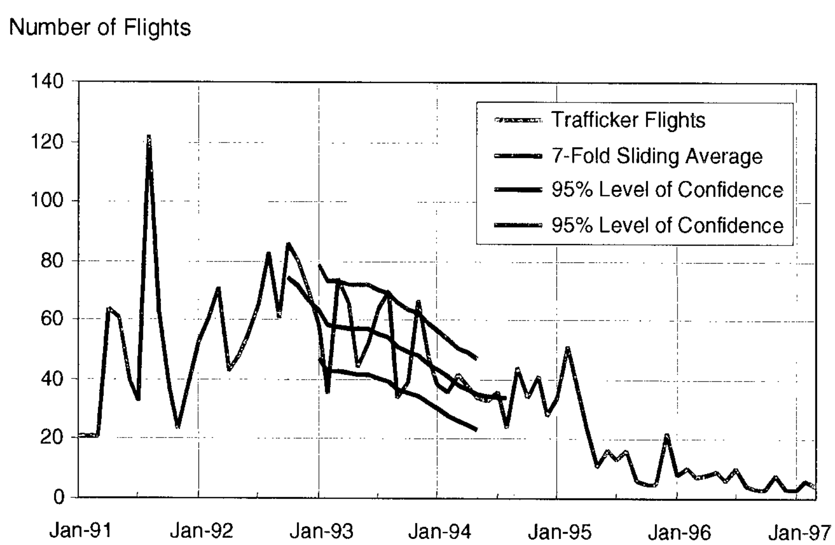


Figure IV-4. Fluctuations of Trafficker Flights and Statistical Expectations

Although these pulses are not random events, examination of the peaks and valleys proves that they are also not seasonal. However, the pulses are strongly autocorrelated at or near 4 months' delay. This quasi-periodicity may reflect either the 3

---

3 Cumulative binomial distribution for 5 or more events of probability 0.05 in a sample of 16 is 0.00086.

months between leaf harvest or the 6 months or less shelf life of coca base. Later we will see an arrested decline in the collapse of the air bridge at 4 to 6 months after the implementation of the shoot-down policy. This suggests that these pulses develop when the air trafficking is under interdiction pressure.

We could think of several possible explanations for these pulses:

- Harvests yields might fluctuate sufficiently to induce pulses.
- Colombian buyers might experience pulses in demand.
- Periodic harvests and purchase cycles in Peru and Colombia might generate mathematical chaos in the trade.
- Traffickers might coordinate their flights to overwhelm the limited interdiction assets.
- The psychology of perceived risk might induce air traffickers to fly when their fellow traffickers appear to be flying – a spontaneous version of the previous explanation.

Since SJ IV lasted 16 months, we broke it into two phases to match other periods and give more periods to the final analysis of events. To avoid biasing either of the two phases, we separated them between two months of low trafficker activity – September 1993 had 34 flights while October had 39. Also, there were no interdictions in either September or October 1993; therefore, our measures will be least sensitive to dividing SJ IV at this point.

b. The Operational Periods

To reduce random fluctuations of our estimate of the interdiction rate, we grouped the months into operational periods lasting 6 to 12 months as shown in Table IV-1. Some periods correspond to an operation, others represent the periods between operations, and still others break up long operational sequences into periods defined by important collateral events such as the attacks on a major Colombian cocaine laboratory complex. Each period, also indicated on Figure IV-3, generally corresponds to distinct shifts in base price. For example, the attacks on Colombian cocaine laboratories in December 1996 through January 1997 caused demand for new coca base from Peru to drop suddenly, and price recovery took more than 7 months.

Table IV-1. Operational Periods for the Analysis of Deterrence

Operational Period	Beginning Date	Duration in months	Comments
Early	Mar-91	8	Air-tons data set begins here.
SJ III	Nov-91	6	SJ III ends soon after FAP shoots US plane.
Post-SJ III	May-92	8	This period is a lull between operations.
SJ IV Phase 1	Jan-93	9	Operation begins in Peru.
SJ IV Phase 2	Oct-93	7	Mid-point break is at dip in trafficker flights.
Post-SJ IV	May-94	10	USG suspends all military support to Peru.*
Early FD/SD	Mar-95	9	Peru begins with renewed USG support.
Transition	Dec-95	12	Temporary stand down of USG support.
CO Labs	Dec-96	7	Major Colombian lab complex attacked.
Sustainment 1	July-97	7	Effect of lab attacks wane.
Sustainment 2**	Feb-98	11	End of interdiction data set for analysis.

* The Colombian Government is determined to engage trafficker flights with lethal force, but the USG must determine whether we can support this within the confines of international law.

** There are no interdiction or flight data for this period; however, there are potential HCl production data.

The remainder of this section describes the sources of interdiction and flight data, discusses their uncertainties, and computes an interdiction probability for each operational period. Readers less interested in these details of this rather involved statistical analysis can go to Section C. Probability of Preventing Trafficking.

2. Trafficker Flights over the Air Bridge

On a monthly basis, the NAS of the U.S. Embassy in Peru reported air traffic that was detected flying over the air bridge. Table IV-2 lists the average number of flights detected per month for each of the operational periods. The USG partially financed and technically supported intelligence gathering and, during operational periods, provided radar D&M. Because the USG provided D&M during operations, these data are more complete than other periods. However, one can see evidence of shifts in operations even among the D&M periods. Phase 2 of SJ IV appears to have been more effective, and the Colombian lab attacks and the final Sustainment 1 Period show continuing decline in traffic.

Detection and monitoring support from the USG was very limited before SJ III, withdrawn during Post-SJ III, and totally withdrawn during the Post-SJ IV Period – including intelligence support. Because base prices were very high during these periods, we believe that traffickers actually transported nearly all of the available base. Therefore, we assume that, during periods of reduced D&M support, the excess to be transported

was comparable to or smaller than the excess during SJ IV. This condition will be used to estimate the undetected fraction of flights. However, restoring this fraction does not affect the deterrence analysis, which primarily depends upon a comparison of periods with D&M and no detection efficiency adjustment.

Table IV-2. Trafficker Flights Corrected for Detection Efficiency

Operational Period	Begin	Detected Flights	Undetected Flights	Estimated Flights
		Monthly	Percent	Monthly
Early	Mar-91	55.0	10%	60.5
SJ III	Nov-91	48.2	0%	48.2
Post-SJ III	May-92	68.5	8%	74.0
SJ IV Phase 1	Jan-93	55.2	0%	55.2
SJ IV Phase 2	Oct-93	43.9	0%	43.9
Post-SJ IV	May-94	35.9	20%	43.1
Early FD/SD	Mar-95	15.0	0%	15.0
Transition	Dec-95	8.2	20%	9.8
CO Labs	Dec-96	3.4	50%	5.1
Sustainment 1	Jul-97	2.1	100%	4.3

The third numerical column of Table IV-2 lists our estimates of the percentage of undetected flights relative to detected flights. These estimates are based on the assumption that virtually all coca for shipment was transported during period between operations, which will be estimated in Section C. Since the USG withdrew intelligence support as well as D&M support during the Post-SJ IV Period, it is easy to understand the 20 percent reduction in detection efficiency versus 8 percent for Post-SJ III.

For later periods after the collapse of the air bridge, traffickers may have been able to use newer technology such as GPS to reduce communication on airfield approach, the internet to conduct business, and file flight plans as licit traffic. These ploys will work to some extent at a low level of trafficking. Since May 1998, the USG withdrew some monitoring support for use in other areas of the world (Ref. 101), which will reduce detection in support of interdiction. Although we estimate that these recent developments allow a leakage that is a large percent of the small residual traffic, even this adjusted total air-bridge traffic would remain a very small fraction of total world wide traffic in coca base – about 3 percent. Other leakage due to bribery of air interdiction personnel is a separate issue not included in this estimate but addressed in Section C.5.

Table IV-2 includes a rough model of the of the above leakage traffic during more recent periods long after the air bridge collapsed. Since the Sustainment 1 Period may have as much as 100 percent leakage, we used this as a target value and assumed a geometric progression of increased leakage leading up it. Even a 100 percent leakage above the detected number of flights is still small in absolute terms, contributing less than 1 percent to the total worldwide coca base transport. We will discuss the implications of these uncertainties in a later section after we introduce the other data sets.

Two other sources of uncertainty are more difficult to estimate and bound: flights missed by intelligence and D&M, and aborted flights that were counted as successful smuggling runs. Note that these two sources of uncertainty act in opposition to one another; intelligence lapses lead to undercounting while aborted flights lead to overcounting. We will estimate the net effect of these and other related sources of uncertainty in the next section where we can use the total material balance of potential coca base to ship to Colombia as a constraint on these uncertainties. Anticipating the results of the next section, we believe these uncertainties leave little bias but contribute significantly to the standard error of the final estimate.

3. FAP Air Interdictions

On a monthly basis, the NAS also reported verified air interdictions. Interdictions include seizure or destruction of the aircraft, loss of drugs, and capture or death of the pilot by forcing the plane down for inspection, by shooting down planes that flee, or by crashes caused by the trafficker aircraft's attempt to escape. Not counted are aborted trafficker flights without loss of plane or drugs and purely accidental crashes due to flying low at night to avoid detection. While the Peruvian Government provided these data to the U.S. Embassy, USG personnel working with Peruvian personnel verified each of these interdictions counted in the NAS data set by observing the evidence of the interdiction. This stringent data quality limitation guaranteed some underreporting, but it also ensures a consistently gathered time series without the distortions due to double-counting.[4]

We analyze the interdiction data for correlations with the number of flights, the availability of USG D&M support, and the enforcement of the FD/SD policy because these will have operational implications for the progress of deterrence in Peru. After this,

4 Double-counting arises whenever individual interdictions are observed or reported by more than one intelligence source but tabulated as separate events.

we compute the statistical uncertainties for each operational period and show that these exceed all other likely sources of interdiction rate uncertainty.

a. Uncorrelated Interdictions and Flights

One would certainly expect that there would be more interdictions during months with more flights to interdict than during quiet months. However, our analysis proves that, with only the exception of the first month of the Early FD/SD Period, there were no significant correlations between number of flights and interdictions.[5] Although the number of flights had dropped to about a fifth of those before the shoot-down policy was implemented, the number of interdictions per month dropped only slightly. This drop explains a third of the remaining small correlation.

Figure IV-5 shows the number of interdictions versus the number of flights during active USG supported operations.[6] Although there are only limited data, there is no evidence for more interdictions during heavy traffic or "pulse" months in either SJ III or SJ IV. However, there are somewhat more multiple interdictions during busy months following the authorization of lethal force. Even these data are a bit misleading. The eight interdictions during March 1995 occurred during the first and busiest month of the operation – well before traffickers had adjusted their behavior.[7] Also, many of the months with two interdictions have only two to six flights and are, therefore, constrained from having more interdictions. If anything, it is the low rate of trafficking that permits interdiction forces to concentrate on detected flights. Before the FD/SD policy, with

---

5 The largest number of verified interdictions in a single month, eight, occurred in March 1995, the first month of the FD/SD policy in Peru and is anomalous because the operation was new and unfamiliar to traffickers. Therefore, this month was dropped from the correlation estimate. Two other peak months with five interdictions, one in SJ III and the other in SJ IV, occurred in months with relatively low traffic. However, three cases with three interdictions per month occurred in relatively busy months. Overall, correlation coefficients of flights versus interdictions per month fluctuate depending upon the time interval one chooses; however, the correlation coefficient for all of the operational periods is only 0.19. The t-test for this is $t = r\sqrt{(n-2)}/\sqrt{1-r^2} = 0.19 \cdot \sqrt{55}/\sqrt{0.964} = 1.43$. This could be expected to be exceeded in 15 percent of all trials. Equalizing the interdictions per month after the shoot-down policy reduced the correlation to 0.12, which can be expected to be exceeded in 39 percent of random trials.

6 Most of the points in Figure IV-5 represent a single month except for the cluster of points with 1, 2, 3, or 4 months of zero interdictions and the point with 1 month of one interdiction. These exceptions had 2 or 3 months plotted on top of one another.

7 The number of interdictions closely approximates a Poisson distribution except eight interdictions in one month is an unlikely extreme. The probability of seeing eight or more events in 56 months when one expects only one event per month is only 6 times in 10,000.

more flights, interdictors appeared to operate at steady pace independent of the trafficker level of activity.

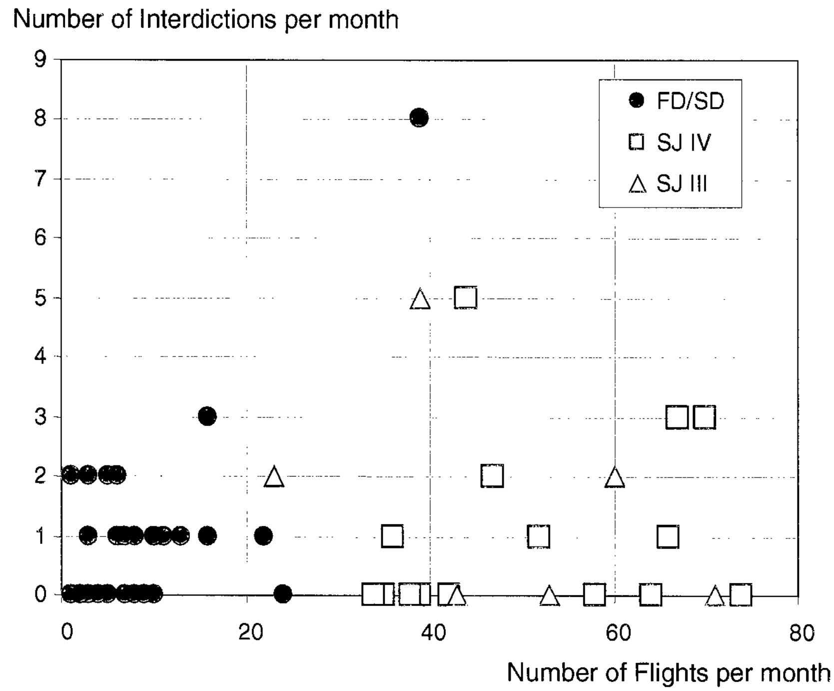


Figure IV-5. Uncorrelated Interdictions and Flights

b. Value of D&M Support during Operational Periods

A simple statistical test shows that USG D&M support provided during operations does increase the interdiction rate per month. Conversely, the FD/SD policy apparently did not significantly change the number of interdictions per month relative to that beforehand. Table IV-3 shows that there were significantly more interdictions during periods with USG D&M support.[8] The monthly rate of interdiction nearly doubled with USG D&M support.

Table IV-4 shows that following the FD/SD policy there was no statistically significant increase in number of interdictions per month.[9] This is remarkable because

---

8 The probability of obtaining a chi square value greater or equal to that for Table IV-3 is only 0.041, demonstrating that the apparent excess of interdictions with D&M support is unlikely to have occurred by chance.

9 The chi square for Table IV-4 would be exceeded in 35 percent of random trials showing there is no evidence for a significant difference between the monthly rates in operations before or after the shoot-down policy.

the number of flights had dropped five-fold or more after the enforcement of the shoot-down policy while the number of interdictions each month changed little.

Table IV-3. Increased Interdiction Rate per month with USG D&M Support

Interdictions	No D&M	D&M	Totals
Actual	14	56	70
Expected	21.9	48.1	70
Months	26	57	83
Monthly Rate	0.538	0.982	0.843

Chi square probability = 0.041.

Table IV-4. Comparable Interdiction Rates per Month Before and After the FD/SD Policy

Interdictions	SJ III & IV	FD/SD	Totals
Actual	25	31	56
Expected	21.6	34.4	56
Months	22	35	57
Monthly Rate	1.136	0.886	0.982

Chi square probability = 0.35.

c. Interdiction Rate and Statistical Uncertainties

As we mentioned in the introduction to this section, we accumulated interdictions by operational period to reduce the statistical counting uncertainties associated with small rates. Table IV-5 gives the total number of interdictions, that is, seized or destroyed aircraft, for each operational period. Since several periods have four or fewer interdictions and the first period has only one interdiction, our estimates of statistical uncertainty must take into account these extreme cases. The binomial distribution is so fundamental that it can provide an appropriate estimate of statistical uncertainty as described in the box underneath Figure IV-5. This proper method yields uncertainty limits, listed as the "upper number" and "lower number" respectively in Table IV-5 that takes into account the finite number of flights as well as the small number of interdictions. Note that these uncertainty limits are not symmetrical about the observed number of interdictions because the totals are small.

d. Adjustment for Undetected Flights and Other Uncertainties

As for flights, there are several reasons to expect less than perfect intelligence and reporting of interdictions. We will address four of these in the following manner:

Table IV-5. Numbers of Interdictions, Uncertainty Limits, and Interdiction Rates

Operational Period	Begin	Number of Months	Number Seized or Destroyed	Upper Number	Lower Number	Detected Flights	Flights plus Interdictions	Interdiction Probability		
								Raw Rate	Upper Rate Estimate	Lower Rate Estimate
Early	Mar-91	8	1	3.28	0.17	440	441	0.0023	0.0075	0.0004
SJ III	Nov-91	6	9	12.63	5.89	289	298	0.0302	0.0437	0.0204
Post-SJ III	May-92	8	6	9.45	3.59	548	554	0.0108	0.0172	0.0065
SJ IV Phase 1	Jan-93	9	10	13.93	6.77	497	507	0.0197	0.0280	0.0136
SJ IV Phase 2	Oct-93	7	6	9.35	3.56	307	313	0.0192	0.0304	0.0116
Post-SJ IV	May-94	10	7	10.51	4.34	359	366	0.0191	0.0293	0.0121
Early FD/SD	Mar-95	9	17	19.38	11.59	135	152	0.1118	0.1435	0.0859
Transition	Dec-95	12	8	10.84	4.88	98	106	0.0755	0.1106	0.0498
CO Labs	Dec-96	7	4	5.80	1.82	24	28	0.1429	0.2415	0.0758
Sustainment 1	Jul-97	7	2	3.78	0.63	15	17	0.1176	0.2522	0.0420

Our method for calculating uncertainty limits on the number of interdictions per operational period mimics error bars on a normal distribution even though the normal approximation does not apply to such small numbers of observations. For a normal distribution, 68.2 percent of the distribution is within plus or minus on standard deviation; therefore, we chose to exclude 15.9 percent of the cumulative binomial distribution at each extreme.

For the upper limit, the cumulative binomial distribution probability that only 15.9 percent of trials have smaller than or equal number of interdictions than the observed number requires that the probability of an interdiction per flight is r_u:

$$P(n \le I, r_u) = 0.159 = \sum_{n=0}^{I} \binom{F}{n} \cdot r_u^n (1 - r_u)^{F-n}$$

where F is the number of attempted flights, that is, observed flights plus interdictions, and I is the number of observed interdictions.

The equivalent expression for the lower limit, r_l, is:

$$P(n \le I - 1, r_l) = 1 - 0.159 = \sum_{n=0}^{I-1} \binom{F}{n} \cdot r_l^n (1 - r_l)^{F-n} .$$

- **Crashes and accidents**: as the interdiction efforts stepped up and traffickers had to fly low and at night over indirect routes, they had more aborted flights and accidental crashes. Risk-taking psychology, however, suggests that a crash caused by trafficker misjudgment poses much less of a deterrent to other traffickers than an interdiction. This is because people are willing to take 1,000 times more risk when they control their own risk-taking than when others have that control (Ref. 11). Although crashes contribute to total coca base tally of the next section, they do not contribute to the psychology of deterrence or the interdiction rate parameter. During operational periods with good intelligence and D&M, we would estimate that crashes and accidents were roughly 25 ±10 percent of reported interdictions. This estimate affects

only the balance of material transported, and the next section will explain that is a very small fraction of the total.

- **Piracy by other traffickers**: some small fraction may be lost to other traffickers and their business dealings, but this small number probably does not contribute to the threshold of deterrence. Piracy may be 5 percent of the interdiction rate – again, a very small fraction of the total base transported.

- **Undetected**: since we are counting only interdictions by the FAP, we assume there are no "undetected" interdictions. However, in the denominator, there is some residual undetected flights. The next section shows that undetected flights tend to cancel against aborted flights counted as completed. Together, these leave an uncertainty of 5 ±5 percent.

- **Not verifiable**: We can imagine only a few reasons not to be able to verify an interdiction: aircraft was shot down over an inaccessible area, shot up on a landing strip too dangerous to investigate, or seized but not reported due to corruption. These are only a fraction of all forms of interdiction; therefore, we conclude that this unverified fraction is at most 25 ±10 percent of the base rate.

Since undetected flights and unverified interdictions simply shift the interdiction rate proportionally, we adjust the raw interdiction rates and limits of uncertainty by multiplying by 1.25/1.05 =1.2 for unverified interdictions and dividing by the 1 plus the percent of undetected flights to obtain the values in Table IV-6.

In addition to sampling statistics, the upper and lower rate statistical ranges should in principle cover the ±10 percent uncertainty on unverified interdictions and a new ±5 percent correction for the uncertainty on the purity of the load as described in the next section. Because these are all small uncertainties to combine with the large statistical uncertainty, we can approximate the overall uncertainty by adding in quadrature. The average uncertainty for both phases of SJ IV is 35 percent, and the overall uncertainty is 37 percent:

$$\sqrt{(0.35)^2 + (0.10)^2 + 2 \cdot (0.05)^2} = 0.37\,.$$

Therefore, the other two contributions to the uncertainty in interdiction rate make a negligible correction to the statistical uncertainties. The last two columns of Table IV-6 show the percentage contribution of the combined uncertainties relative to the base interdiction rate estimate for each operational period.

Table IV-6. Interdiction Rates with Adjustments for Undetected Flights

Operational Period	Begin	Interdiction Probability: Adjusted Rate	Upper Rate Estimate	Lower Rate Estimate	Upper Percent	Lower Percent
Early	Mar-91	0.0025	0.0081	0.0004	229.1%	-82.7%
SJ III	Nov-91	0.0362	0.0524	0.0245	44.7%	-32.5%
Post-SJ III	May-92	0.0120	0.0192	0.0073	59.2%	-39.6%
SJ IV Phase 1	Jan-93	0.0237	0.0336	0.0163	42.1%	-30.9%
SJ IV Phase 2	Oct-93	0.0230	0.0365	0.0139	58.8%	-39.5%
Post-SJ IV	May-94	0.0191	0.0293	0.0121	53.1%	-36.7%
Early FD/SD	Mar-95	0.1342	0.1722	0.1031	28.3%	-23.2%
Transition	Dec-95	0.0755	0.1106	0.0498	46.5%	-34.0%
CO Labs	Dec-96	0.1143	0.1932	0.0606	69.0%	-47.0%
Sustainment 1	Jul-97	0.0706	0.1513	0.0252	114.4%	-64.3%

4. Interdiction Rate by Operational Period

To visualize the changes in interdiction rate from one operational period to the next, along with uncertainties and effect of undetected flights, Figure IV-6 shows the abrupt rise in interdiction rate and spreading of the uncertainty band following the enforcement of the shoot-down policy. Because the raw interdiction rate still lies well within the uncertainty range, the adjustments do not dominate our results.

C. TRANSPORTED COCA BASE AND POTENTIAL FOR TRANSPORT

Now that we have P_I, we turn to estimating P_t, the fraction of all coca base that was transported over the air bridge relative to the total that might have been transported. To do this, we account in an approximate manner for all the coca base Peru might have produced in each operational period, breaking this amount into fractions that would have been available for transport and that which was detected as being transported. Let us begin by examining the raw data.

Figure IV-7 shows the raw data for the tonnage carried across the air bridge by traffickers against a background of the total potential cocaine production of Peru. For reference, we also show on an arbitrary scale the UNDCP price series for coca base and the periods of major air interdiction operations.

The raw data for Peru's total potential cocaine production comes from CNC satellite surveys of total cultivation conducted over a month or so as soon as the clouds

break in late summer. We chose September as the typical survey month and linearly interpolated between successive Septembers to estimate monthly production for the intervening months. Although crop estimates are made only once a year and there are typically four harvests in Peru, the base can be stored for up to 6 months, which justifies a linear interpolation as a reasonable estimate. The CNC applies the best estimates of cocaine production per hectare of cultivation to estimate potential cocaine. Since not all coca goes to illicit trade to Colombia, we must make adjustments for production of coca base and diversion to other uses.

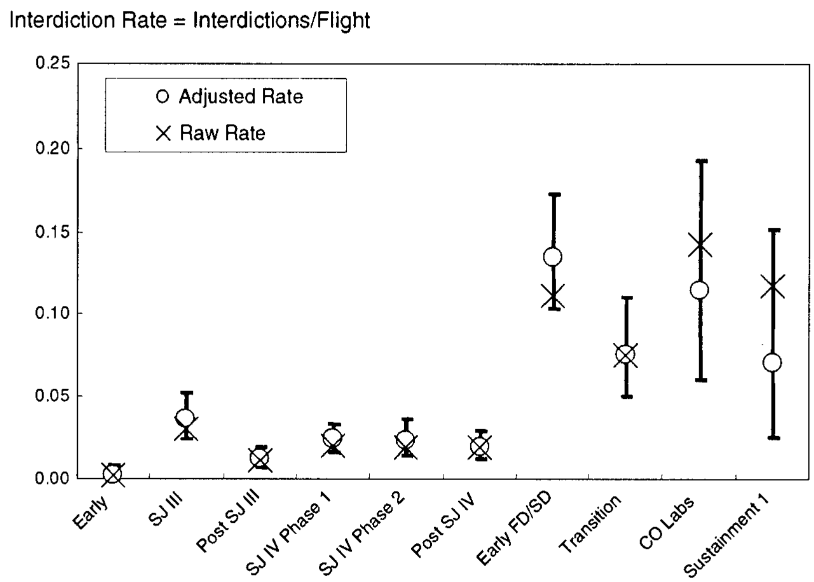


Figure IV-6. Adjusted and Raw Interdiction Rates and Statistical Uncertainties by Operational Period

For each load reported as successfully flown to Colombia, the TAT, also located in the U.S. Embassy in Peru, estimated the load's weight based on intelligence reports or, lacking that, the known capacities of the detected aircraft. The TAT tons include the capacities of the smuggler aircraft and often the actual load size available for transport, which varies with fuel load and length of trip. There is a good reason for trusting these monthly estimates as independent and objective. If one compares the traffic pulses of flights during SJ IV, shown in Figure IV-3, with the pulses in Figure IV-7, one sees that the pulses are even more pronounced in tons than in flights. Because this tonnage is so unpredictable month to month, these data could not have been "adjusted" by the TAT to match any preconceived notion of a yearly total.

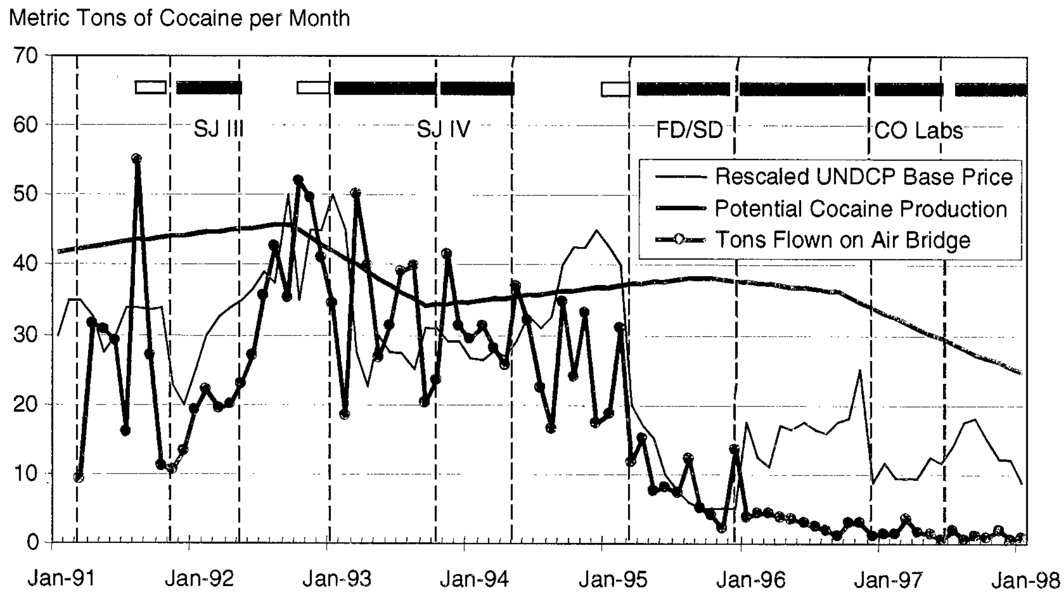


Figure IV-7. Raw Data for Air Tons Carried over Air Bridge and Potential Cocaine Production

The remainder of this section identifies the components of the total coca budget for Peru and uncertainties on each of these components for each operational period. Readers not interested in these details should skip to Section D, "Analysis of Deterrence Across the Air Bridge."

1. Catalog of Sources of Uncertainty

Because there are so many sources of uncertainty to be addressed, we tabulate them here along with a summary of our results as a guide for readers while going through the subsequent detailed discussion and analysis. Table IV-7 lists the sources of uncertainty for the major categories: total potential cocaine, the tons transported over the air bridge, and the tons interdicted. The residual "excess," i.e., the potential minus the transported and the interdicted, is an estimate of the coca base that might have been transported if there were no inefficiencies or deterrence. Since we expect very little deterrence during the Post-SJ III, SJ IV Phases 1 and 2, and Post-SJ IV Periods, we also expect the excesses during these period to be statistically indistinguishable from zero as shown in Table IV-7. The columns are to be interpreted as follows:

Table IV-7. Sources of Uncertainty for the Material Balance Before, During, and After SJ IV

Source of Uncertainty	Adjustment	Variation	Frequency	Threshold	Estimation Methods
Potential Cocaine*	102.5%	9.1%	of 100%		Project BREAKTHROUGH adjustment to CNC estimate
Conversion to HCl (CNC)	0%	0%	Constant**	Major	Absorbed in DEA purity adjustment below
Sampling statistics	0%	< 5%	YTY***	Major	Satellite survey sampling uncertainty
Missed areas	0%	5%	Periodic***	Major	Comparison with UNODCP
Harvest variation	0%	In above	YTY	Major	Assumed relatively constant except for El Nino
Licit sales and uses	-4%	2%	Constant	Major	Compare historical cultivation with DEA estimates
Illicit internal consumption	-5%	2%	Constant	Major	Compare historical cultivation with DEA estimates
Direct sales-HCl or ground transport	-5%	5%	Constant	Major	DEA estimates during peak years assumed going to Europe
Tons of Base over Air Bridge	-86.0%	8.7%	of 86%		Estimated by flight by TAT and reported monthly
Sampling statistics	0.0%	5%	Period	Minor	With estimated load size uses counting statistics on flights
Reduced D&M periods	Not SJ IV	8 and 20%	Period	Minor	Tailored to expected traffic during low D&M period
Purity relative to cocaine	5%	5%	Proportional	Minor	Comparison of various conflicting DEA estimates
Missed flights	about -20%	< 5%	Proportional	Minor	Indirectly estimated by consistency with material balance^
Overestimate of plane loads	3%	In above	Proportional	Minor	Limited degree of uncertainty
Aborts counted as completed	about 20%	In above	Proportional	Minor	Indirectly estimated by consistency with material balance^
Lost after counted	N/A	N/A	Proportional	Minor	Ignored -- willing to fly and HCl counted in material balance
Blend with licit & bribery	Exp model	N/A	Period	Minor	Recent saturation of leakage (Colombian flow)
Replacement of lost Bolivian coca	Exp model	N/A	Period	Minor	Recent saturation (direct flows east and west)
Interdictions	-2.0%	38.1%	of 2%		Reported by GOP to NAS and verified by USG
Sampling statistics	0%	35%	Period	Major	Counting statistics scaled by aircraft loads
Not verified	-25%	10%	Proportional	Major	Comparions with other intelligence estimates
Crashes and accidents	-25%	10%	Proportional	Major	Comparions with other intelligence estimates
Piracy by other traffickers	-5%	5%	Proportional	Major	Comparions with other intelligence estimates
Estimated Excess					Estimated residual after adjustments
Raw differences	12.0%	8.7%	Calculated	N/A	Sampling statistics on potential and tons
Systematics only	3.7%	7.2%	Calculated	N/A	Variations due to known systematics
Accumulated adjustments	3.7%	11.8%	Calculated	N/A	Variations combined by quadrature of all quantities
Adjustments used in overall analysis	4.8%	11.0%	Calculated	N/A	Final totals without estimated corrections to interdictions.

Adjustments are positive if they increase the excess and negative, if they decrease the negative.
Frequency of change of variation assumed for the analysis: YTY, year-to-year; MTM, month to month; and Period, Operational Period.
* Potential cocaine has a baseline of 102.5 percent because the CNC estimates of 1993-94 are 2.5 percent below Project BREAKTHROUGH's.
** Although constant in metric tons, given here as percentage of SJ IV periods.
***Estimates at beginning and end of yearly survey period are averaged; therefore, reciprocal square of total standard error is the sum of the reciprocal squares of individual standard errors.
^See Section IV.C.2 for a full discussion leading to these estimates.

- **Adjustment**: This is the incremental shift from the raw baseline value. The sign indicates whether it increases of decreases the "excess," which is the remainder from the total potential production minus the amounts transported or interdicted. Adjustments are percentages of the parent category – potential cocaine, tons, and interdictions -- with the latter two being only a fraction of the total cocaine.
- **Variation**: This is the contribution to the uncertainty range from this source of uncertainty designated in the row heading.[10] Note that the first entry for the major category is the combined uncertainty for all contributions to that major category.
- **Frequency**: This code indicates how often to expect variations. The first row for each major category is the percentage weighting for the contribution to the overall total uncertainty shown under "Accumulated Excess" in the "Accumulated adjustments" row.
- **Threshold**: This column summarizes the degree to which each source of uncertainty will influence the empirical estimates of the deterrence threshold P_{min} to be calculated in Section IV.D.3. "Minor" indicates that empirical estimates of P_{min} will be proven insensitive to tons over the air bridge.
- **Estimation Methods**: These are summary comments about the methods of analysis for estimating or bounding uncertainties.

2. Overall Detection Efficiency Adjustment and Other Consistency Issues

Before going through the sources of uncertainty item by item, we should address a gap in the observational data indicated by the heavy-framed box. We do not have direct estimates of "missed flights," "overestimates of plane loads," or "aborts counted as completed." While some planes might not be full or have more fuel on board than anticipated, the overestimates are expected to be quite small, of order 3 percent. Missed flights resulting from detection inefficiencies narrow the excess. Conversely, aborted flights widen the excess because they might be counted twice: first on the aborted attempt and again on a follow-up attempt. Thus, the two potentially significant uncertainties – missed versus aborted – partially cancel leaving a smaller residual adjustment.

Analysis of the internal consistency of all of the contributions to the excess places a limit on the plausible size of the above three sources of uncertainty for which we do not have a direct estimate. It also demonstrates that our estimates of the variations are somewhat too large. Subsection "a" below limits the range of adjustment to that of the

10 We will treat each of these as standard errors.

systematic uncertainties, 7.2 percent, and the variation to less than 5 percent. Since the uncertainties on missed or aborted flights are believed to be mostly from counting statistics, we can indirectly estimate the size of these unknowns to about 20 percent, as explained in subsection "b."

a. Consistency of Variation Estimates with Raw Excesses

The excesses obtained from the raw data are remarkably close for Post-SJ III, SJ IV Phase 1, and SJ IV Phase 2 being only 13.9, 10.7, and 12.2 percent respectively. Their differences are at most 3.2 percent followed by 1.7 percent. Although one has to make a D&M correction to the Post-SJ III Period, this would *narrow* the excess. Since the systematic adjustments in Table 7 apply to all periods, its already small adjusted excess leaves little latitude for the D&M efficiency adjustment. The adjusted excess for Post-SJ III differs by less than 2.4 percent, while the SJ IV Periods differ by less than 0.5 percent.

Since the period-to-period variation for the raw excess (second row of estimated excess in Table IV-7) is 8.7 percent, we consider the likelihood that the period-to-period difference in excess could be only 0.5 percent, 2.4 percent, or even 3.2 percent, respectively. This 8.7 percent variation includes only the sampling statistical variation from period to period for the potential cocaine and for the number of flights carrying coca base over the air bridge. The chance of these small differences given the large standard errors for numbers being differenced is standard statistical problem. The chances are no greater than 3.2, 15, and 21 percent, respectively.[11] Since the raw estimate of variation on the excess is already pressing the limits of plausibility, the overall estimate of 11.8 percent (next to last row of Table IV-7) is clearly too large. With this larger variation, the chance of the 3.2 percent difference drops to 15 percent.

Now consider the systematic variations, which are shaded in gray in Table IV-7. They combine in weighted quadrature[12] to give an overall standard error variation of 7.2

---

11 The probability of a difference being so close given a large standard error on each quantity in the difference is a standard calculation. The standard error on the difference is $\sqrt{2} \cdot 0.087 = 0.123$. The chance that the difference would be 0.005 or less can be calculated from the cumulative normal distribution and is $\Pr(-0.005/0.123 \le x \le 0.005/0.123) \cong (0.01/0.123)/\sqrt{2\pi} = 0.032$. Note that if the means of the two distributions were unequal, this probability would be even smaller. Similarly, the more excact results for 2.4 and 3.2 percent are 15 and 21 percent, respectively.

12 The variations on flights and interdictions must be weighted by their fractional contribution to total cocaine, i.e., 0.86 and 0.02 respectively.

percent. Although our estimates of the excess during SJ IV ranges between 4.3 and 4.8 percent, less than the 7.2 percent, the approximate nature of our assignment of adjustments allows us to close the excess if done in a consistent manner. Thus, the estimated variation is a more reliable number.

Overall, the net contribution of the missed flights, overestimated loads, and second attempts on aborted flights must be comparable or less than the variation of the adjustment 7.2 percent. Similarly, the variation of these three undetermined quantities must be much less than the statistical variations of the raw data; otherwise, the internal consistency of the raw data for the three tightest operational periods would be even less likely. We, therefore, assign the limit of 5 percent to the net variation of the three undetermined sources of uncertainty. Added in quadrature with the previous 8.7 percent, 5 percent more yields a total variation of 10 percent – well above a plausible limit.

b. Limits on the Unknown Detection Efficiency

Now we can estimate the plausible upper limits on the size of the individual undetermined adjustments given that their combined variation is less than or equal to 5 percent. Such an estimate can be compared with military judgment for such operations. Assuming that the variations all arise from counting statistical fluctuations, we can write an equation relating the variations:

$$
\begin{aligned}
VAR_{excess} &= VAR_{missed} + VAR_{aborts} \\
&= \left(\sqrt{N_{missed}}\right)^2 + \left(\sqrt{N_{aborts}}\right)^2 \\
&= N_{missed} + N_{aborts} \\
&\leq \left(N_{total} \cdot \sigma_{excess}\right)^2 \\
&= (307 \cdot 0.05)^2 = 236
\end{aligned}
$$

Where the *N's* refer to the additional or fewer flights during the operational period resulting from misses and aborts (estimated loads contribute too little to include), and σ_{excess} is our upper limit on the variation of the excess. If $\sigma_{excess} = 0.035$, the sum would be reduced to 116.

There is a second constraint; the difference of the missed and aborted flights cannot exceed the adjustment on the excess. This non-negative difference is:

$$\left|N_{missed} - N_{aborts}\right| \leq N_{total} \cdot 0.072 = 307 \cdot 0.072 = 22$$

These constraints bound a permissible zone of values as shown in Figure IV-8.

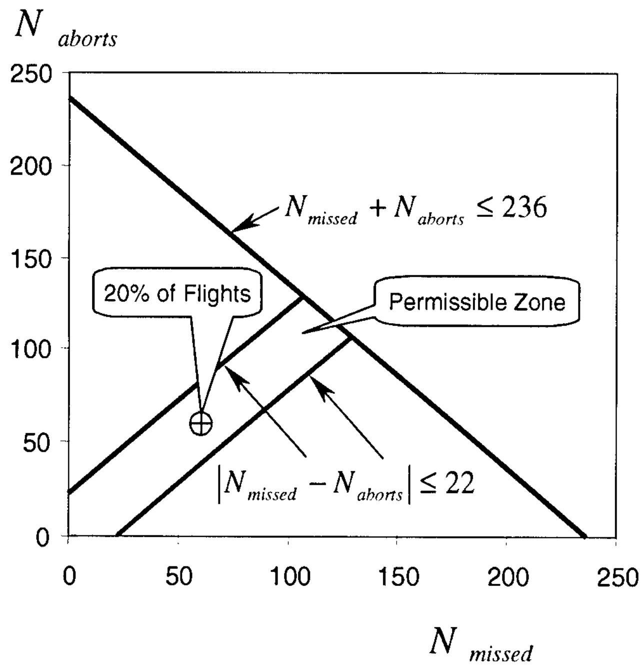


Figure IV-8. Limits on Missed and Aborted Flights

As a percentage of 307 total flights, the extreme upper right corners of the permissible region in Figure IV-7 are 42 percent for one unknown and 35 percent for the other. However, if one or the other unknown was smaller than the extreme value, both would be close together, constrained by the 7.2 percent (22 flights) limit on their difference. With a smaller 116 total instead of the 236, the extreme adjustment becomes only 22 percent with 15 percent for the other. Given the unlikely chance of reaching the extremes, even for the larger limit, we choose 20 percent as the "typical" adjustment for both missed flights and aborted flights. This is compatible with military judgment when there is good intelligence and D&M support as there was during SJ IV and other interdiction operations.

Now we review the remaining estimates of adjustments and uncertainty in Table IV-7.

3. Potential Coca for Transport

The upper limit on coca for transport comes from the sums of the interpolated CNC estimates for monthly production in September of each year.[13] To estimate the

---

[13] Note that if our procedure were used to make *yearly* production estimates, these would differ from the CNC's because our method correctly includes an adjustment for production continuity from year to

metric tons available for transport to Colombia over the air bridge, we must adjust the raw totals according to the following known diversions and uncertainties:

- **Conversion to HCl**: This changes slowly and, as Chapter II explained, has not changed appreciably during the 1990s; its contribution is negligible.
- **Sampling statistics**: Potential total cocaine production estimate itself is uncertain due to sampling errors, but we estimate this year-to-year variability as ±5 percent.[14]
- **Missed areas**: In the dynamic Colombian environment, there is an ongoing controversy among CNC, U.S. State Department, and UNODCCP about total cultivation; however, Peru has been either stable or in decline from 1993 onward, which reduces the likelihood of significant missed cultivation. We assign a ±5 percent uncertainty because UNODCCP estimates vary relative to CNC's but are predominantly *lower*, which would constrain our "excess" more than it is already.
- **Harvest variation**: Although El Nino caused low harvests, this was during a period of decline that does not affect our analysis, and other periods are considered constant within the accuracy of other uncertainties. We assume that the statistical variation uncertainty covers the uncertainty in harvests as well.
- **Licit sales and uses**: Some fraction of Peru's potential cocaine production from Cuzco goes to licit internal consumption and export sales through a government-controlled monopoly.
- **Illicit internal consumption**: In both producing areas and larger towns and cities, many Peruvians have become habituated to the readily available refined coca products.
- **Direct sales**: There has always been some cocaine HCl production within Peru, which is sold directly to markets in Europe, the Orient or possibly Mexico bound for the U.S. Such production does not cross the air bridge but, rather, is shipped off the Pacific Coast of Peru or transported south to Bolivian traffickers supplying Europe. We also include the small ground transportation and riverine leakage typical of the SJ IV timeframe to this category.
- **Seizures**: These are not listed in Table IV-7 because before 1998 they amounted to less than one percent of potential production and are ignored in

year. This difference can be as large as 30 percent of the change from one year to the next in Colombia.

[14] The CNC estimates the annual sampling variation to be 10 percent, but judges missed areas to be less than we do at 5 percent. Overall, our two 5-percent variations combine to 7.1 percent vice CNC's 10 percent.

this analysis (Ref. 37; Ref. 57, 1994-1999). Seizure operations and the threat of seizures, nevertheless, have utility. These operations gain intelligence about the illicit business, and the threat of seizures adds considerable cost and increases competition for the traffickers.

a. Licit Production and Internal Consumption

Before the cocaine epidemic, Peru had 17,000 hectares of production for export, internal use, and whatever low-level illicit market existed at that time. Most of this cultivation was located in Cuzco, and we assume that this historical consumption forms a constant background even today. Operation BREAKTHROUGH estimates Cuzco's potential cocaine productivity as less than that for the rest of Peru. Using this lower productivity and scaling to 17,000 hectares equivalent yields 3.6 metric tons per month as the background value. This was 9.4 percent of total production during SJ IV Phase 1. Operation BREAKTHROUGH also estimates that Peruvians consume about 5 percent of their total illicit production internally. A comparison of the precise Project BREAKTHROUGH estimates scaled for 1995 compared with those given by the CNC's conventional methods showed that the former was 2.5 percent greater than the latter, which is the size of Cuzco's licit production if converted to cocaine (Ref.17; Ref. 5, Peru, 1995). Therefore, we began with a baseline of 102.5 percent and subtracted 4 percent for licit sales and uses and another 5 percent for illicit internal consumption.[15] Since these values have been consistently reported over the early 1990's, we estimate the variation to be only ±2 percent on each. Because these totals have been stable even before the cocaine epidemic, we subtract these diversions as constant amounts rather than scaling them with changes in total production.

b. Direct Sales

The DEA consistently reported 10 percent of production was processed into cocaine within Peru by traffickers (Ref. 37). We expect that the majority of this was sold directly to traffickers with Europe, the Orient, or shipped to Mexico – circumventing the air bridge to Colombia. Taking 10 percent as a range for the baseline period of SJ IV, our estimate would be 5 percent ±5 percent.

---

[15] This compares well with the UNODCCP estimate of internal consumption based on a prevalence of 17.2 percent of the population consuming, which translates at U.S. consumption per user as 5 percent of Peru's production (Ref. 1).

c. Adjustment and Variation for Potential Cocaine

Because of the historical stability of the survey uncertainties and the licit sales, we consider these to form a constant diversion in metric tons for all periods. During peak years, internal consumption creates a habituated user population and direct sales create steady markets. We assume that together these formed a constant diversion during the peak years. Production averaged 36.5 metric tons per month for our baseline period of SJ IV Phase 1 and 2; therefore, the constant diversions would be 14–2.5=11.5 percent or 4.2 metric tons per month.

The first set of contributions to the uncertainties include sampling statistics and harvest fluctuations plus missed areas. These fluctuate year to year or periodically. The remaining uncertainties spread as the sum of independent contributions. Thus, the overall uncertainty combining all contributions in quadrature is the following:[16]

$$\sqrt{(0.05^2 + 0.05^2)/2 + 0.02^2 + 0.02^2 + 0.05^2} = 0.076$$

Thus, 7.6 percent of 36.5 metric tons per month is an overall uncertainty of ±2.8 metric tons per month. Table IV-8 summarizes these results.

4. Transported Coca Base

As listed in Table IV-7, several sources of uncertainty led to adjustments in TAT estimates of the tonnage of potential cocaine carried over the air bridge.

- **Sampling statistics**: The statistical fluctuations for the finite sample of flights contribute a substantial percentage to the variation.
- **Reduced detection and monitoring**: During the Post-SJ III and Post-SJ IV Periods, reduced D&M support decreased the average number of aircraft detected per month relative to the two SJ IV Periods. Assuming that nearly all available coca base was flown, the excess should be small during these periods, and this provides a means of estimating the flights not detected due to reduced D&M or intelligence support.

---

16 Because both the year before and the year after average to produce the interpolated values for production, the yearly uncertainties combine as sums of reciprocals squared. Thus, each yearly variance is the sum of statistical and missed area variances, and the variance of the average is one-half this yearly variance.

Table IV-8. Total Possible Peruvian Production and Potential for Transport to Colombia

Operational Period	Begin	Raw Potential MT/mo	Diverted* HCl MT/mo	HCl for Transport MT/mo	Net Uncertainty MT/mo	Percent
Early	Mar-91	43.1	4.2	38.9	2.8	7.2%
SJ III	Nov-91	44.5	4.2	40.3	2.8	6.9%
Post-SJ III	May-92	44.9	4.2	40.7	2.8	6.9%
SJ IV Phase 1	Jan-93	38.1	4.2	33.9	2.8	8.3%
SJ IV Phase 2	Oct-93	34.9	4.2	30.7	2.8	9.1%
Post-SJ IV	May-94	36.3	4.2	32.1	2.8	8.7%
Early FD/SD	Mar-95	37.9	4.2	33.7	2.8	8.3%
Transition	Dec-95	36.7	4.2	32.5	2.8	8.6%
CO Labs	Dec-96	31.8	4.2	27.6	2.8	10.2%
Sustainment 1	Jul-97	26.7	4.2	22.5	2.8	12.4%

* Fixed diversions include licit consumption, illicit internal consumption, and illicit direct export not over the air bridge.

- **Purity relative to cocaine**: Because coca base from Peru may not convert directly to an equal weight of cocaine, it might take more flights of the observed load capacity to transport the available coca base.
- **Missed standard flights**: Intelligence is never perfect, and some flights would go undetected.
- **Overestimate of plane loads**: Since some flights did not carry a full load, intelligence calculations based on the observed type of aircraft alone would correspondingly overestimate the amount carried.
- **Aborts counted as completed**: Some flights might abort outside Peruvian monitoring and yet be counted as completed trips. This material would have to be flown later and most likely counted a second time.
- **Lost after counted**: Trafficker flights that crash or are otherwise lost after being counted do not bias our analysis because they are "willing" flights, and the drugs are accounted for properly because they are not available to be flown and counted a second time.
- **Blend with licit or bribery**: Smuggler flights based on properly filed flight plans may not be effectively traced as illicit, and bribed officials might not "detect" or report an illicit flight. Although present at a low level, these processes are not believed to contribute greatly to Peruvian traffic until the later years during which time the absolute number of flights was small.
- **Replacement of lost Bolivian coca**: As Bolivian coca quality declined, Peruvian coca that could not be transported north could travel south and east

to fill the shortage in European and world markets. This traffic does not contribute to our analysis of the air bridge to Colombia because it was small until the most recent couple of years.

- **Interdicted flights**: These individual adjustments must be included in the total material balance but are grouped here to form a small contribution to the total.

a. Purity Adjustment

The DEA estimated coca base purity from seized loads and, in 1994, conducted Operation BREAKTHROUGH, which scientifically measured the purity of coca base produced by typical lab processing. Unfortunately, these two estimates of purity disagree. Seized purity in the early 1990's was reported as 60 percent (Ref. 102) while Operation BREAKTHROUGH (Ref. 17) reported 82 percent purity from their laboratory experiments with volunteer illicit chemists. With 82 percent pure base, Colombian laboratory chemists can produce export purity cocaine at a ratio of 1:1 by weight. Other sources indicate that purity increases as transport becomes riskier. Clearly, this makes sense because additional refining is a small cost of the transportation under high-risk conditions. Conversely during periods of low risk, traffickers would likely ship as much and as soon as they could – purity might suffer.

Since our analysis of interdiction hinges on a comparison of two periods with good D&M support and relatively high risk, SJ IV versus post-shoot-down periods, we will adjust our estimates of purity toward the higher limit. For all periods, we assume a weight ratio of coca base to cocaine of 95 ±5 percent.

b. Sampling Statistics, Load Sizes, and Reduced D&M Adjustment

Although the number of flights reported by NAS and the tonnage reported by TAT track closely, they are not directly proportional because the size of aircraft used by traffickers varied from one period to another.[17] These changes in aircraft load were responses to the interdiction threat – longer indirect flights require more fuel and larger aircraft, both affect load size.

Since we know the number of flights carrying the aggregate tonnage, we can estimate the counting fluctuations for the number of flights and convert this to a percent uncertainty either in flights or in aggregate tonnage as follows. During SJ IV Phase 1,

[17] The correlation coefficient between flights and TAT tons over months is 0.93 and the regression of flights and months explaining tons has an $R^2 = 0.81$.

there were 9 months of 55.2 flights per month, or 497 flights. The counting uncertainty on this is its square root, or 22.3, which is 4.5 percent. Similarly, SJ IV Phase 2 had 7 months of 43.9 flights for a total of 307 and an uncertainty of 5.7 percent. We chose ±5 percent as a representative fraction for Table IV-7.

Table IV-9 summarizes the detected flights, the detected air tons, and their ratio indicating the typical capacity of aircraft used during each period. It also gives adjusted tons of HCl equivalent transported over the air bridge taking into account 95 percent purity, reduced detection efficiency with less D&M support, and recent leakage. Counting fluctuations and the uncertainty on the purity adjustment yield an overall uncertainty for the total number of flights. Note that after the FD/SD policy, the counting fluctuations become the dominant uncertainty on the estimate of tons carried.

c. Coca on Interdicted Flights

The coca base that is either seized or destroyed on interdicted flights contributes to the total material balance. Generally, this is a small fraction of the total; however, we believe that traffickers transported nearly all available coca base during periods between operations; thus, even small amounts need to be accounted in the total. Also, a comparable fraction of losses that were not detected could be expected from the sizable uncertainties on the interdiction rate. The amount lost on verified interdictions can be estimated by scaling the number of interdicted flights by their average load weights taking into account the purity correction. Table IV-10 gives this result. Note that this contribution is often less than a percent of potential total and at most 3.0 percent.

Table IV-9. Trafficker Flights Load and Capacity Characteristics

Operational Period	Begin	Detected Flights	Detected Air Tons	Load per Flight	Adjusted Air Tons*	Counting Variation
		Monthly	MT/mo	Kg	MT/mo	Percent
Early	Mar-91	55.0	26.1	475	27.3	4.8%
SJ III	Nov-91	48.2	17.3	360	16.5	5.9%
Post-SJ III	May-92	68.5	38.2	558	39.2	4.3%
SJ IV Phase 1	Jan-93	55.2	33.3	604	31.7	4.5%
SJ IV Phase 2	Oct-93	43.9	30.0	685	28.5	5.7%
Post-SJ IV	May-94	35.9	26.6	742	30.4	5.3%
Early FD/SD	Mar-95	15.0	8.2	544	7.8	8.6%
Transition	Dec-95	8.2	4.0	484	4.5	10.1%
CO Labs	Dec-96	3.4	1.5	452	2.2	20.4%
Sustainment 1	Jul-97	2.1	1.1	500	2.0	25.8%

*Adjusted Air Tons is reduced by assuming 95 percent purity, and adjusted for detection inefficiencies during periods of reduced D&M support.

Table IV-10. Coca on Interdicted Flights

Operational Phase	Interdicted Flights	Load per Flight	Load Purity	Lost HCl	
	No/mo	Kg	Ratio	MT/mo	Percent
Early	0.150	475	0.950	0.068	0.2%
SJ III	1.746	360	0.950	0.596	1.3%
Post-SJ III	0.890	558	0.950	0.472	1.1%
SJ IV Phase 1	1.307	604	0.950	0.749	2.0%
SJ IV Phase 2	1.009	685	0.950	0.656	1.9%
Post-SJ IV	0.824	742	0.950	0.581	1.6%
Early FD/SD	2.013	544	0.950	1.040	2.7%
Transition	0.740	484	0.950	0.340	0.9%
CO Labs	0.588	452	0.950	0.252	0.8%
Sustainment 1	0.303	500	0.950	0.144	0.5%

d. Summary of Excess Residuals by Period and Combined Variations

We now have sufficient information to compute the material balance from both the raw data and the adjusted quantities across all sources of uncertainty. The residuals from these material balance summaries are the excess losses – either undetected or abandoned because it could not be transported.

Table IV-11 shows the material balance and residual excesses for the *raw* data. Here, we used the load size and number of interdictions to compute the metric tons per month lost in interdictions. The key feature of this summary is the stability of the excess values before any adjustments were made for the three periods: Post-SJ III and SJ IV Phases 1 and 2. These differ at most by 3.2 percent. More striking is their rank ordering in which SJ IV had the smallest excesses, Post-SJ III the next smallest, Post-SJ IV the next most, and so on. This ranking makes perfect sense operationally given our knowledge of available D&M support and the interdiction conditions during each period.

We will use the balance without the initially unknown adjustments to tons over the air bridge and the estimated corrections to losses from interdiction in the remaining analyses of this report. Examination of Table IV-7 shows that our estimates of variations combine to yield 8.7 percent for the statistical fluctuations on the raw data, 11.0 percent for the variation without the initially unknown adjustments and estimated corrections to interdictions, and 11.8 percent with the variations of the initially unknown adjustments included. The only difference implied by dropping these estimated quantities is 1.1

percent in the excess – a difference that does not affect the deterrence model or operational considerations.

Table IV-11. Excess Metric Tons Not Flown – Estimate from Raw Data

		Raw Data					
Operational Period	Begin	Total Potential	Flown	Interdicted	Excess		Ascending Rank Order
		MT/mo	MT/mo	MT/mo	MT/mo	Percent	Number
Early	Mar-91	43.1	26.1	0.1	16.9	39.3%	5
SJ III	Nov-91	44.5	17.3	0.5	26.7	59.9%	6
Post-SJ III	May-92	44.9	38.2	0.4	6.2	13.9%	3
SJ IV Phase 1	Jan-93	38.1	33.3	0.7	4.1	10.7%	1
SJ IV Phase 2	Oct-93	34.9	30.0	0.6	4.2	12.2%	2
Post-SJ IV	May-94	36.3	26.6	0.5	9.2	25.2%	4
Early FD/SD	Mar-95	37.9	8.2	1.0	28.7	75.7%	7
Transition	Dec-95	36.7	4.0	0.3	32.4	88.4%	8
CO Labs	Dec-96	31.8	1.5	0.3	29.9	94.3%	9
Sustainment 1	Jul-97	26.7	1.1	0.1	25.5	95.5%	10

Table IV-12 summarizes each major category as an adjusted quantity and shows the excess for each period and the uncertainties on those excesses. The "Percent 1" is excess expressed as a fraction of the raw potential tons, and "percent 2" is expressed as a fraction of the adjusted total potential. The upper and lower uncertainties are based on adjusted total potential and correspond to the asymmetry of the interdiction variations. Note that the asymmetries from small interdiction statistics are indistinguishable here because interdictions are such a small percent of total material balance.

5. Recent Alternative Markets

By 1998-99, coca base prices in Peru once more reached the breakeven point necessary to sustain current cultivation and induce harvesting of overgrown but surviving coca plants. Thus, a combination of alternative coca markets must have evolved to support the 1998 level of production of about 13.4 metric tons per month, roughly 160 metric tons annually, going to these alternative markets. Counter-narcotics groups within the U.S. Embassy in Peru believe that several components contribute to this new access to market demand.

Table IV-12. Excess Metric Tons Not Flown – Estimate from Adjusted Quantities

Operational Period	Begin	Adjusted Quantities: Total Potential MT/mo	Adjusted Quantities: Flown MT/mo	Adjusted Quantities: Interdicted MT/mo	Excess MT/mo	Excess Percent 1	Excess Percent 2	Excess Uncertainty Upper Percent	Excess Uncertainty Lower Percent
Early	Mar-91	38.9	27.3	0.1	11.6	26.8%	29.7%	8.7%	8.7%
SJ III	Nov-91	40.3	16.5	0.6	23.3	52.3%	57.7%	7.7%	7.6%
Post-SJ III	May-92	40.7	39.2	0.5	1.0	2.2%	2.4%	9.4%	9.4%
SJ IV Phase 1	Jan-93	33.9	31.7	0.7	1.4	3.8%	4.3%	10.4%	10.4%
SJ IV Phase 2	Oct-93	30.7	28.5	0.7	1.5	4.2%	4.8%	11.6%	11.6%
Post-SJ IV	May-94	32.1	30.4	0.6	1.2	3.2%	3.7%	11.1%	11.1%
Early FD/SD	Mar-95	33.7	7.8	1.0	24.9	65.7%	73.9%	8.7%	8.7%
Transition	Dec-95	32.5	4.5	0.3	27.7	75.4%	85.1%	8.8%	8.8%
CO Labs	Dec-96	27.6	2.2	0.3	25.1	79.0%	91.1%	10.3%	10.3%
Sustainment 1	Jul-97	22.5	2.0	0.1	20.3	76.1%	90.3%	12.7%	12.7%

Percent 1 is of the raw total potential. Percent 2 is of the adjusted total potential.

- Traffic to the south to replace Bolivia's collapsing production of high-grade coca base or HCl for European markets. Bolivia could have produced 150 MT of HCl annually in 1998 based on CNC satellite surveys (Ref. 5, Peru) and Yungas' diversion of 50 percent of production to illicit markets. Because of this collapse, Peru may have redirected traffic to supply from 60 to 80 metric tons annually for Europe. This is only a plausible estimate because there is little systematic surveillance southward from Peru.

- Traffic to the west into Peruvian cocaine HCl production laboratories and subsequent smuggling directly to Europe may contribute to this redirected traffic. These direct sales appear to be expanding given this year's large seizures in both Peru and Europe of Peruvian HCl.

- River trade northward into Colombia is arduous, slow, costly, and dangerous, but some seizures prove that traffickers do use this avenue to an unknown extent.

- Filing licit flight plans that are not systematically checked, bribing officials to avoid interdiction, and leakage through a reduced radar surveillance coverage add to the riverine traffic northward to Colombia. The combined riverine and leakage of air traffic by these new means could add another 80 metric tons annually to Peru's current market as speculated by some in the U.S. Embassy in Peru.

- River traffic and other indirect smuggling routes could quickly revert to direct flights over the air bridge if the interdiction force stood down. As for the diversion to the European market, it is a result of the successful interdiction efforts in Bolivia and may or may not revert to the air bridge if the air interdiction operations stood down. Nevertheless, we count both of these diversions as successes of the air interdiction campaign because they

challenge the trafficker's most profitable option. Secondary follow-up operations need to reduce access to these new markets, operations such as river patrols by Peruvian navy and police, alternative development bringing better government security, increased surveillance of coca regions and trafficking routes, and interdiction of key processing chemicals such as potassium permanganate.

6. Components of Production by Operational Period

Figure IV-9 shows the profile of changing contributions to Peru's total potential cocaine HCl production capacity over the operational periods. CNC production estimates and anecdotal comments about interdiction and detected traffic support the extrapolation to the Sustainment 2 Period. We show an estimate of the diversion to "reversible alternative markets" growing exponentially until demand absorbed the "excess" in early 1999. The white zones of the bars in Figure IV-9 represent "excess" production that could not reach market over the air bridge because of effective air operation deterrence. For all periods, we represent the magnitude of the combined variations as a lower left to upper right cross-hatch bar. Because these variations exceed even the total estimated air tons for the last three periods, no solid red area remains and the variations were truncated.

As we mentioned above, during both phases of SJ IV and the periods just before and after SJ IV, the excess is less than the uncertainties in our estimates. Note especially that the large excesses during the early FD/SD Period illustrate the coca not making it to market, which caused coca prices to fall and farmers to abandon fields.

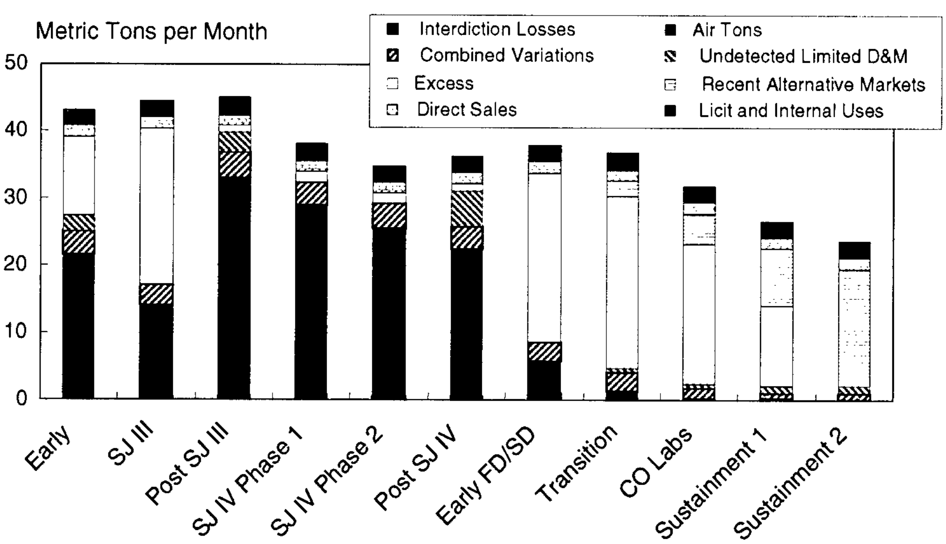


Figure IV-9. Cocaine Production and the Fraction Carried by the Air Bridge to Colombia

The solid red bars represent the adjusted air tons going to Colombia, and the red upper left to lower right cross hatch represents the undetected flights. The short black band at the bottom of the bars represents losses to interdiction. In combination, the red cross hatch, red bars, and black bands make up the total attempted air trafficking. If the successful air trafficking were divided by the total that was available for transport, we would obtain the "successful flights" percentage. Smaller percentages of successful flights represent more effective interdiction and deterrence.

D. ANALYSIS OF DETERRENCE ACROSS THE AIR BRIDGE

We now pick up the discussion of deterrence where we left off after the introduction to Section C of this chapter. The last two sections provided data from USG supported Peruvian air operations to block air trafficking of coca base from growing regions in Peru to cocaine laboratories in Colombia. These data can now be compared with the deterrence model developed in Section A, and, if they match quantitatively, the Peruvian data provide a calibration for the important threshold P_{min} for FD/SD operations.

Equation (2) of Section A is the deterrence model, and Figure IV-2 plotted equation (2) showing zones separated by different values of P_{min}. Here, Figure IV-10 once again shows the deterrence model but now overlaid with data from the operational periods against the air bridge and two earlier transit-zone operations. Table IV-13 summarizes both the adjusted and raw data values that are plotted in Figure IV-10, while the error ranges for the adjusted data come from the discussion in the pervious two sections.

Table IV-13. Data from Operational Periods Plotted in Figure IV-10

		Based on Adjusted Values			Based on Raw Data		
Operational Period	Begin	Interdiction Rate	Successful Flights	Prevented Flights	Interdiction Rate	Successful Flights	Prevented Flights
		Probability	Probability	Probability	Probability	Probability	Probability
Early	Mar-91	0.0025	0.7015	0.2985	0.0023	0.6060	0.3940
SJ III	Nov-91	0.0362	0.4079	0.5921	0.0302	0.3889	0.6111
Post-SJ III	May-92	0.0120	0.9641	0.0359	0.0108	0.8518	0.1482
SJ IV Phase 1	Jan-93	0.0237	0.9352	0.0648	0.0197	0.8758	0.1242
SJ IV Phase 2	Oct-93	0.0230	0.9304	0.0696	0.0192	0.8613	0.1387
Post-SJ IV	May-94	0.0191	0.9453	0.0547	0.0191	0.7334	0.2666
Early FD/SD	Mar-95	0.1342	0.2302	0.7698	0.1118	0.2154	0.7846
Transition	Dec-95	0.0755	0.1386	0.8614	0.0755	0.1077	0.8923
CO Labs	Dec-96	0.1143	0.0801	0.9199	0.1429	0.0488	0.9512
Sustainment 1	Jul-97	0.0706	0.0905	0.9095	0.1176	0.0401	0.9599

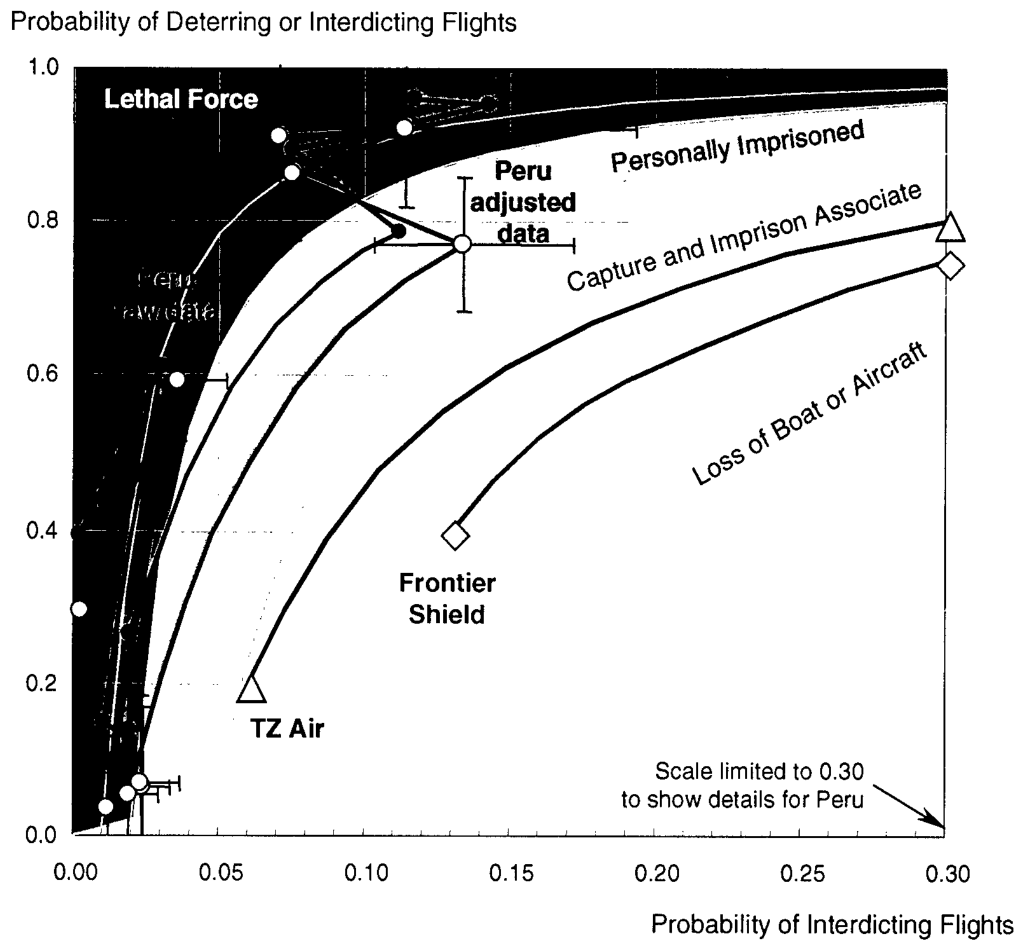


Figure IV-10. Deterrence Model Showing Peruvian Counter-Air Operational Periods and Transit-Zone Operations of Counter Air and Frontier Shield

The three lines dividing these zones are defined by threshold values of $P_{min} = 0.02$, 0.05, and 0.13, respectively. Each of these zones and two others represent different consequences of interdiction for traffickers.

- Lethal Force ($P_{min} \leq 0.02$): With the threat of lethal force, traffickers begin to quit challenging the interdictors when P_{min} reaches about 2 percent. Much below this threshold, however, traffickers are willing to accept the risks as a cost of doing business at risks of about 0.7 percent or less.
- Personally Imprisoned ($0.02 \leq P_{min} \leq 0.05$): If experienced traffickers anticipate a severe sentence if they are captured, they will begin to be significantly deterred in this range of interdiction probabilities.
- Capture and Imprisonment of an Associate ($0.05 \leq P_{min} \leq 0.13$): Those who have not experienced prison life may be more difficult to deter and require thresholds in the range from 5 to 13 percent. This zone characterizes two

major transit-zone operations: the counter-air operations over the Caribbean and Frontier Shield against go-fast boats in the eastern Caribbean. Although including arrests and imprisonment, which render the consequences comparable to imprisonment of associates (Ref. 16), these operations consisted mostly of loss of aircraft or boats and the drugs. There were interdictions at both the points of embarkation and debarkation.

- Loss of Boat or Aircraft ($0.13 \leq P_{min} \leq 0.30$): This zone of interdiction threat also assumes loss of the drugs.
- Loss of Drugs ($0.30 \leq P_{min} \leq 1.00$): Although this region is not shown in Figure IV-10 because the interdiction scale is truncated to show more detail for small percentages, interviews with inmates and observed behavior in the transit-zone interdiction support a threshold in this region.

1. Deterrence Underlying the Collapse of the Air Bridge

The dark blue line and open circles in Figure IV-10 show the complex sequence of interdiction levels and prevented trafficker flights for each of the operational periods overlaid on our deterrence model. Each point is the interdiction level along the horizontal axis and one minus the "successful flights" representing prevented trafficker flights along the vertical axis.

The red line and filled circles in Figure IV-10 show the sequence of periods expressed in ratios of the raw data for flights, interdictions, and potential cocaine production. Differences between the black and red sequences indicate the effect of all the adjustments. Note that most operational periods for both sequences follow the general shape of the deterrence model profile. Most of the open black circles and red dots fall just inside or just outside the deterrence model profile for determined by a P_{min} value of 0.015. The exceptions are the first and last operational periods and the early FD/SD Period. The early period can be explained as being well before the interdiction methods were refined, the last period has very few data with only two interdictions as revealed by large horizontal error bars, and the early FD/SD Period includes the traffickers' transition to the new more intimidating conditions. We now discuss this sequence and the transition in more detail.

a. Operations before the Shoot-Down Policy

Although not sanctioned by the U.S. Government, Peruvian fighters "accidentally" fired upon traffickers during SJ III, and approximately 60 percent of the traffickers quit flying. However, SJ III ended soon after a Peruvian fighter mistakenly

shot into a USG C-130 airplane killing one U.S. airman. After tighter constraints on the use of lethal force were negotiated and enforced for the next operation, SJ IV, the traffickers ignored the interdictions even at a slightly higher interdiction level than in SJ III. As far as these data can discern, no traffickers were deterred during SJ IV, yet they did get paid more for the risks, which somewhat depressed coca base prices in Peru.

The statistical uncertainties on the interdiction rate ranged upward to 5 percent in SJ III corresponding to a P_{min} of 3 percent and upward to 4 percent during SJ IV. The SJ III value was just above the deterrence threshold for lethal threat and the SJ IV value was below threshold for a force-down only policy.

b. Vigorous Pursuit of the Shoot-Down Option

Following the Presidential Finding in December 1994 authorizing support to interdictions that might end with lethal force, the USG resumed intelligence and D&M support to the FAP. With this support, the FAP was able to interdict enough flights over the next 9 months to deter 70 percent of the traffickers.

Other than the first month, May 1995, the increase in interdiction rate from 1.9 percent to 13 percent was due more to the decline in trafficker flights than from an increase of interdictions per month. Remember, we showed that interdictions per month were nearly constant even in the first two periods after the enforcement of the post-shoot-down policy. Nevertheless, during this Early FD/SD Period, traffickers continued to operate well outside the "lethal force" deterrence zone of Figure IV-10 into the "personally imprisoned" deterrence zone in spite of the lethal threat. However, unwilling to sustain these losses, trafficker operations collapsed back within the "lethal force" deterrence zone for the next operational period, the transition period. Another 9 percent were deterred, and the remaining traffickers were less aggressive in challenging the interdiction forces – the interdiction rate dropped by nearly half. This transitional process raises several questions:

- Why was there a lag in the level of deterrence causing the early FD/SD Period to shift outside the deterrence model zone for "lethal force"?
- What role did ordinary attrition of the more aggressive traffickers play in this transition?
- Can we learn from examining the transition in more detail?

A close examination of this critical Early FD/SD Period shows that trafficker flights fell off exponentially from their peak in February 1995, one month before the

interdictions began supporting the policy, until November 1995. Figure IV-11 shows this exponential decline and its characteristic decay time is 3.9 months. For this simplest of all representations of a decay process, the statistical agreement is quite good – a chi square probability of 0.23 verifying that the variations not explained by the model could be random fluctuations. Thus, it took several months for the deterrent effect to achieve its full impact. This probably represents the time it took pilots and traffickers to fully appreciate the changed conditions.

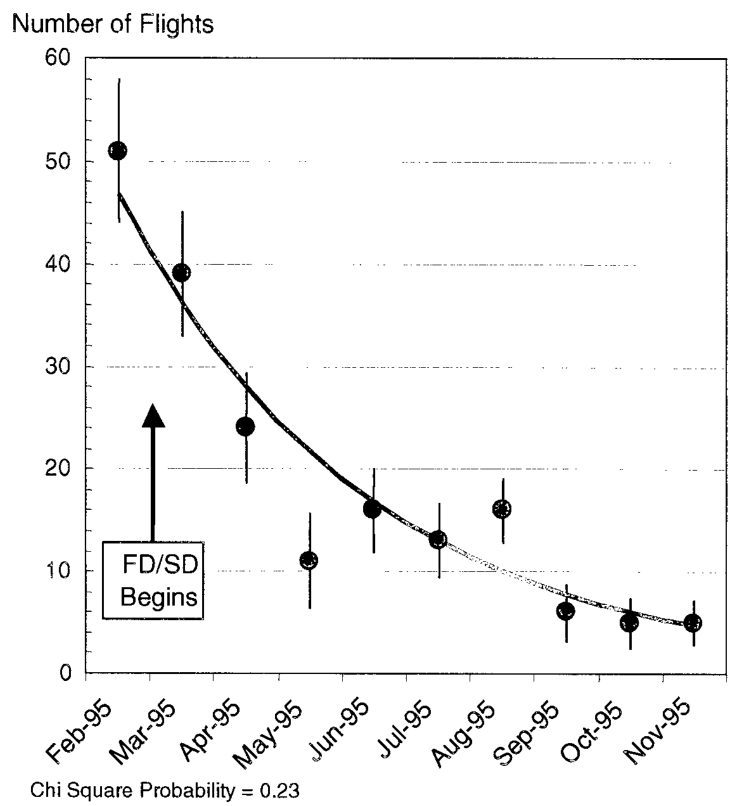


Figure IV-11. Exponential Decline of Flights after FD/SD Policy

It is possible that the slight rise in the data from July to September represents a residual "pulse" in traffic. Since coca base ages and loses its value in 6 months, it may be possible that some traffickers tried to wait out the interdictions until they had to ship or lose their investment. If there were a delayed push to smuggle, the exponential trend would have fallen even more sharply from its February 1995 peak.

The exponential decay also implies that each successive month has on average 22.6 percent fewer flights than the last. Since the interdiction rate is only 12 percent, an attrition of 12 percent per month cannot explain a 23 percent per month decline in traffic.

From a pilot's perspective, an interdiction rate of 12 percent backed by lethal force would be daunting. If a pilot expects to smuggle six times in his career – the average number for inmates in federal prisons – surviving six flights with an 88 percent chance of success on each yields only a 46 percent chance of surviving all six attempts. Less than 50:50 chances of survival cannot be very attractive to pilots. A 12 percent loss rate also rapidly depletes any trafficking organization's pool of pilots.

The attrition principle is well known among military planners – even a 2 to 3 percent attrition rates per campaign day quickly destroys the effectiveness of an opposing force. To see why, consider an operation lasting only 2 weeks at an attrition rate of loss of only 3 percent per day. At the end of the 2 weeks, continuing losses would have cost air force 35 percent of its pilots and planes. Such a loss would render an air force unit ineffective and require it to be reconstituted.

Traffickers appear to operate by a different model, but with much the same result. Experienced imprisoned traffickers interviewed in the Rockwell study said that the owners of drugs must lose shipments at an average rate of 30 percent of attempts before they would quit (Appendix A, section F.4). However, pilots begin to refuse to fly against 2 or 3 percent chance of lethal interdiction and, once they know the odds, fewer than 20 percent are willing to fly against a 7 percent chance of lethal interdiction.

c. Sustainment of the Interdiction Operations

After 9 months of enforcement of the shoot-down policy, the interdiction forces stood down in late November of 1995 for more than a month. Traffickers quickly took advantage of this opportunity because what had been 5 or 6 flights per month jumped to 22 flights in December of 1995 and fluctuated between 7 and 10 flights per month for the next 8 months. These additional flights corresponded to an increase in coca base prices to just below breakeven levels. Nevertheless, Figure IV-10 shows that the interdiction and trafficking levels for this transition period placed it well into the lethal deterrence zone, and the increased capacity of the air bridge most likely does not rise to statistical significance as seen in prices on U.S. Streets.

In December of 1996 and January of 1997, the Colombian Government carried out large-scale raids against a complex of cocaine HCl laboratories, capturing more than 7 metric tons of cocaine and a great deal of chemicals and fuel. This destruction of a major and active laboratory complex, estimated to have been refining 35 percent of all of the cocaine from Colombia, created a shortage that rippled down all the way to U.S. streets. Traffickers operating across the air bridge at first saw a drop in demand followed

by a surge as Colombian's rebuilt laboratories elsewhere. Aggressive attempts to fly coca base corresponded to an increase in the interdiction rate from 7.6 to 11.4 percent. This surge within the lethal zone could not be sustained, and current levels of trafficking represent more cautious trafficker operations well within the lethal force deterrence zone of Figure IV-10.

2. Deterrence Thresholds

There is another view of deterrence that holds operational lessons as well as providing a more direct way to estimate the deterrence thresholds for lethal threats from the Peruvian experience. In this view, we calculate interdiction relative to the *potential* coca base production to be transported rather than the number of actual flights. Remarkably, the deterrence fraction based on the total potential number of flights is directly related to $P_{\min}$ and is nearly independent of the willingness to smuggle. Once the interdiction fraction exceeds the deterrence threshold, P_{min}, and stays there, air trafficking collapses. The reason for the collapse is that a constant rate of interdictions relative to potential flights becomes an increasing fraction of the actual number of flights as trafficker willingness diminishes. Examining deterrence in detail from this perspective yields several important operational lessons.

a. Interdictions and Trafficking Relative to Total Potential Trafficking

In this subsection, we explain the underlying mathematics. The following two subsections present tabular and graphical results of this reformulation of the variables in the deterrence model.

Let us designate the interdiction fraction of total *potential fraction* of traffic by P_f. For a given month, this is the number of interdictions in that month, I, divided by the maximum number of potential coca base flights for that month, F_M. For an operational period, we can estimate F_M by dividing the amount of coca base to ship by the average weight of a load.

The other variable in this new perspective is the familiar willingness to smuggle but expressed as a function of I, F_M, and F, where F designates the number of successful trafficker flights for the month. With these definitions, we can transform our previous expression for willingness:

$$W \equiv \frac{F+I}{F_M} = \left(\frac{P_I}{P_{\min}}\right)^{-\alpha}$$

$$= P_{\min}^{\alpha} \cdot \left(\frac{I}{F+I}\right)^{-\alpha} = P_{\min}^{\alpha} \cdot \left(\frac{F+I}{F_M}\right)^{\alpha} \cdot \left(\frac{I}{F_M}\right)^{-\alpha}$$

$$= (P_{\min} \cdot W)^{\alpha} \cdot P_f^{-\alpha}$$

where we have multiplied and divided by F_M in the second line. Because α is very nearly 1.0, and may turn out to be exactly 1.0 as more is understood about deterrence, the W nearly cancels from the opposite sides of the equation. Algebraically, we can see this by rewriting the above into two useful expressions, one for $P_{\min}$ and the other for P_f:

$$P_{\min} = P_f \cdot W^{\frac{1-\alpha}{\alpha}} \tag{3}$$

$$P_f = P_{\min} \cdot W^{\frac{\alpha-1}{\alpha}}. \tag{4}$$

Since the empirical findings depend upon P_f and W, we need to express these and their uncertainties in terms of the known variables I, F_M, and F, and their respective uncertainties. Table IV-14 gives the result. There is an upper and lower uncertainty on P_f because we know that the upper uncertainty range of I is larger in absolute value than the lower one. Here, all of the uncertainties are independent from one another, and all of the equations relating the known variables to the new ones are mathematically well behaved. Therefore, the standard errors on the parameter set imply individual uncertainties[18] on the variables, P_f and $P_{\min}$, which simply add in quadrature to obtain the uncertainties on the new variables.

b. Lethal Interdiction Threshold Derived from the Operational Periods

Now for each operational period, we can estimate the important deterrence threshold parameter, $P_{\min}$, assuming that the deterrence model is correct and that its exponent is the one obtained from the inmate interview data, $\alpha = 1.029 \pm 0.068$. If our model is correct, we should obtain a consistent value for the lethal interdiction threshold.

[18] These individual uncertainties are close to the partial derivatives of the new variables with respect to each parameter and multiplied by the standard error on those parameters, respectively.

Table IV-14. Inferred Interdiction Thresholds for Operational Periods

Operational Phase	Begin	Parameter Set: Inter-dictions	Parameter Set: Flights	Parameter Set: Potential Flights	Fractions of Potential: Interdicted Fraction	Fractions of Potential: Willing Fraction	Uncertainties: Upper Interdiction Fraction	Uncertainties: Lower Interdiction Fraction	Uncertainties: Willing Fraction
		No/mo	No/mo	No/mo	Rate/mo	Rate/mo	Rate/mo	Rate/mo	Rate/mo
Early	Mar-91	0.125	60.5	86.2	0.001	0.703	0.003	-0.001	0.076
SJ III	Nov-91	1.500	48.2	118.1	0.013	0.421	0.006	-0.004	0.047
Post-SJ III	May-92	0.750	74.0	76.7	0.010	0.974	0.006	-0.004	0.102
SJ IV Phase 1	Jan-93	1.111	55.2	59.1	0.019	0.954	0.008	-0.006	0.101
SJ IV Phase 2	Oct-93	0.857	43.9	47.1	0.018	0.949	0.011	-0.007	0.106
Post-SJ IV	May-94	0.700	43.1	45.6	0.015	0.961	0.008	-0.006	0.105
Early FD/SD	Mar-95	1.889	15.0	65.2	0.029	0.259	0.009	-0.007	0.032
Transition	Dec-95	0.667	9.8	70.7	0.009	0.148	0.004	-0.003	0.020
CO Labs	Dec-96	0.571	5.1	64.2	0.009	0.089	0.006	-0.004	0.019
Sustainment 1	Jul-97	0.286	4.3	47.4	0.006	0.097	0.007	-0.004	0.026

Using equation (3) above and the values of the variables from Table IV-14, we obtain the values of $P_{\min}$ shown in the first numerical column of Table IV-15. The uncertainty, shown in the next column, is dominated by variation of P_f alone.[19] The reason that W has so little influence on the result is that its exponent is nearly zero:

$$\frac{1-\alpha}{\alpha} = \frac{1.029-1}{1.029} = 0.028\,.$$

Even if we add the uncertainty, it makes little difference because the results range between –0.034 and +0.084. If these exponents were zero, then any value of *W* raised to that exponent would be 1.0; this limit is almost reached with this model. For example, the difference between a *W* of 0.25 to one of 0.75 raised to the 0.028 power is only 0.003.

---

19 The uncertainties on both W and α add less than at most 2 percent to that of $P_{\min}$ by itself. We also combined the upper and lower uncertainties from *I* because they are very close. With a list of $P_{\min}$ values for periods with lethal operations, we could use least squares fitting for the several estimates of a global best fit $P_{\min}$ as shown in Table IV-16.

Table IV-15. Inferred Thresholds and Uncertainties

Operational Phase	"P_{min}" Threshold	"P_{min}" Uncertainty
	Rate	No/mo
Early	0.0015	0.0025
SJ III	0.0130	0.0039
Post-SJ III	0.0098	0.0038
SJ IV Phase 1	0.0188	0.0048
SJ IV Phase 2	0.0182	0.0059
Post-SJ IV	0.0154	0.0048
Early FD/SD	0.0301	0.0054
Transition	0.0100	0.0034
CO Labs	0.0095	0.0041
Sustainment 1	0.0064	0.0043
E. FD/SD-Mar95	0.0231	0.0054

The last row is the early FD/SD Period without the first month, March 1995, in which 8 traffickers were interdicted and deterrence had just begun.

Figure IV-12 compares the lethal deterrence thresholds for each of the ten operational periods. Nearly all are consistent with the indicated best-fit value, that is, the Early and Early FD/SD Periods have uncertainty ranges that do not come close to spanning the fitted value. The "Early" did not involve lethal threats, was not supported by USG D&M, and did not have a mature approach; it was not included in the fit. Table IV-16 summarizes various least square fits to a common lethal interdiction threshold, $P_{\min}$. Since a cumulative chi square probability of 0.50 is expected at random, all of the fits are plausible, but the third and fifth through seventh are the best fits. None of the fits include the first period, and the worst fit includes the Early FD/SD Period. The last two thresholds involve a modification of the Early FD/SD Period. Finally, all but the first two are within ±0.0008 of the selected best level of 0.0116, that is, 1.16 percent.

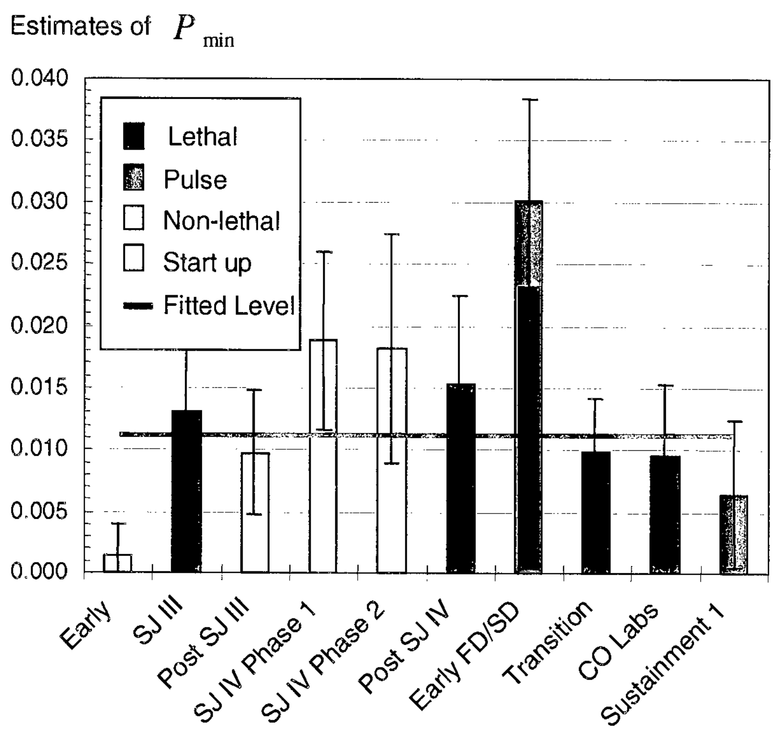


Figure IV-12. Inferred Thresholds and Best Fit for Lethal Interdiction

Table IV-16. Threshold for Lethal Deterrence Fitted to Several Operational Periods

Fitted Set of "P_{min}" Values	Fitted Threshold	Standard Error	Chi Square	Chi Square Probability
All but first period	0.0125	0.0020	7.74	0.46
Without first and last case	0.0133	0.0021	6.60	0.47
All but first and FD/SD	0.0115	0.0020	3.04	0.93
All shoot-down periods	0.0117	0.0025	6.01	0.20
Three shoot-down periods	0.0108	0.0028	0.27	0.87
All Shoot-down periods*	0.0111	0.0025	2.94	0.57
All SD* and Post-SJ IV	0.0116	0.0023	3.26	0.52

*March 1995 with eight interdictions was deleted from the Early FD/SD Period.

c. Discussion of Distinct Operational Periods

The Early FD/SD Period had the most intense lethal threat and mature D&M support. Initially, it was extremely effective, interdicting 8 of 47 flights in the first month, nearly 15 times the fitted threshold level. Throughout this period, however, traffic continued to decay toward the low-level steady state. To assess the degree to which this transient first month impacted the threshold estimate, we deleted that month and recalculated the period as shown in the last row of Table IV-15. The difference is

dramatic, dropping the P_{min} estimate from 3.0 to 2.3 percent. Although the uncertainty range still does not intersect the best fit, it now comes close.

The Post-SJ III and both SJ IV Periods did not enforce a lethal threat and are shown in green in Figure IV-12. With D&M support in SJ IV, the implied interdiction threshold was well above the fitted value for the lethal periods yet, as we know, traffickers ignored the threat. Interdictions would have to risen well within the "imprisoned self" zone to deter traffickers with the SJ IV threat.

Two periods indicated in pale red did pose a lethal interdiction threat, but deserve more attention as special cases. During the Post-SJ IV Period, the Peruvian Air Force had decided to pursue a lethal interdiction strategy, and achieved an interdiction rate above P_{min} yet without an immediate collapse of air trafficking. There are at least three competing ways to explain this:

- Three of the seven interdictions during this period did occur after the USG began support to Colombia and Peru, but the Peruvian forces were preoccupied with a border war and were less effective. It is possible that these interdictions did begin the deterrence.
- It is possible that the dynamics of the interdiction model requires interdictors to exceed the threshold by enough to convince traffickers continued smuggling it is really hopeless – get beyond a reasonable doubt. After the initial change in attitude, sustained interdiction close to threshold would continue to reinforce the deterrence.
- Finally, we have assumed that the exponent in our model equals that derived from interviews with incarcerated smugglers. If a larger exponent applied, the model would have a slightly different interpretation of these initial phases – a topic we address in the next subsection.

Our suspicion is that some of both the first and second apply while the third is a subject of continued research. In any case, this period is very consistent with the overall fit to a threshold.

The last period in pale red is the "Sustainment 1," which falls below the fitted overall threshold. This could be a statistical fluctuation, but it may be a real decline in interdiction effectiveness. However as we shall go into more later, once the traffickers have been deterred, they may be reluctant to start up again in earnest. If an effective interdiction force can be brought to bear at modest cost to the counterdrug forces – there is little future in challenging those interdiction forces just to bring on another devastating interdiction campaign.

d. Importance of the Interdiction Fraction

We now present another method of graphing the deterrence model and point out some operational lessons from this new perspective. Figure IV-13 plots the operational periods and their uncertainty ranges in terms of the interdiction fraction, P_f, versus the fraction willing to smuggle, W. Note the very different scales on the horizontal and vertical axes. Vertically, W spans the full range from 0.0 to 1.0, while horizontally, P_f spans only 0.0 to 0.05. Tracing the operational history, one can see the dip at SJ III followed by traffickers ignoring the operations through Post-SJ IV and the subsequent collapse during and following the Early FD/SD Period.

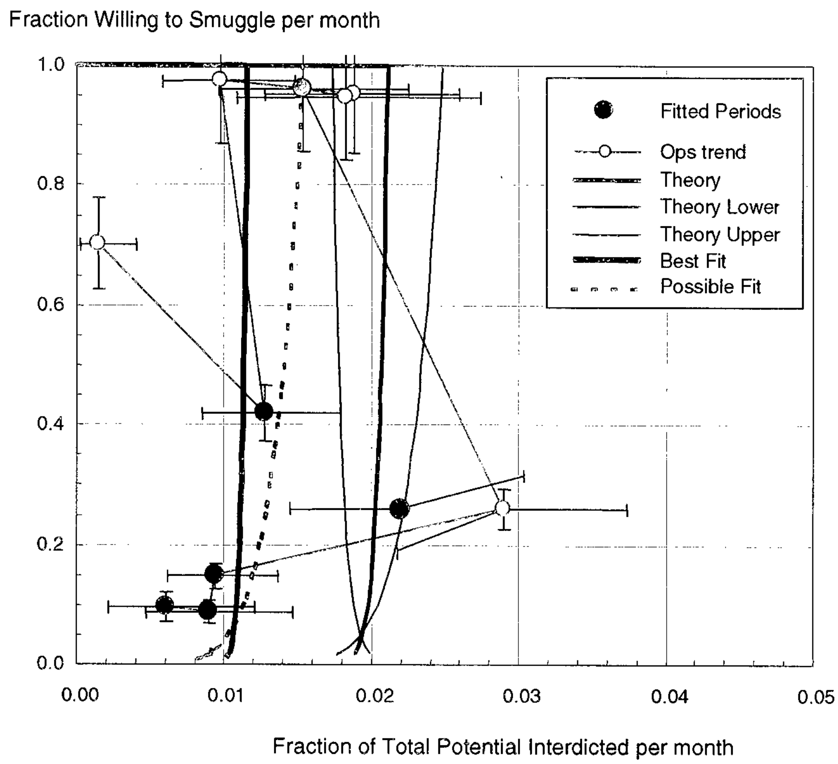


Figure IV-13. Collapse at Constant Interdiction Fraction: Theory, Operational Period, and Best Fit

Overlaid on the operations, Figure IV-13 shows in dark blue the lower zone boundary for "imprisoned self" from the theoretical model derived from inmate interviews. To the left in red is a model trace representing the lethal interdiction conditions from the Peruvian experience. This trace has the same exponent as the theoretical model but uses the fitted threshold for lethal interdiction operations. Although these two traces break at different threshold values, they share the common theoretical form. Beginning at zero interdiction threat, all traffickers are willing to smuggle as

indicated by the W value of 1.0. With increasing fractions being interdicted, the operating point moves right until reaching the threshold at $P_{\min}$. The red trace breaks downward at a threshold $P_{\min}$ of 1.16 percent, while the blue trace breaks further to the right at a threshold of 2.11 percent. This is logically consistent since the "lethal" threshold from real operations is less than that for the interview results representing "capture and imprisonment."

At the bottom of the plot, the curves actually stop at a minimum W value greater than zero. This value is the residual willing to smuggle *knowing* they will be caught – a feature of the model and a result of inmate interviews. This minimum value is:

$$W_{minimum} = P_{\min}^{\alpha} = P_f .$$

Thus, at $W_{minimum}$, all flight attempts are interdicted, and willingness and interdiction fractions are equal.

Operational Lesson: As deterrence takes hold, we learn a major operational lesson from this plot. A constant interdiction fraction sufficient to initiate deterrence also appears sufficient to cause trafficking to collapse – *as long as the interdiction fraction can be maintained at its threshold level.* In Peru, the operational constraint was the number of mission-ready interceptors of the Peruvian Air Force. As previous sections showed, the number of interdictions per month remained nearly constant. It fell only slightly faster than the level of coca production in Peru because the later operational periods shown in Figure IV-13 are only slightly left of the threshold.

This result depends upon the exponent in the model. The best-fit theoretical model has an exponent slightly greater than 1.0 in absolute magnitude, that is, 1.029. This causes the slight retrograde leftward bend to the heavy red and blue lines as willingness drops from $W = 1.0$ to ever smaller values. Thus, maintaining a constant fraction of interdictions would move the operating point further above threshold conditions and intensify the deterrent effect as more traffickers quit.

However, if the absolute value of the exponent were slightly less than 1.0, such as at the lower end of the uncertainty range, the situation changes. The thin blue line to the left of the central heavier line represents the lower uncertainty range of the theoretical model zone boundary. It has an exponent less than 1.0 in absolute value, 0.967. Here, the thin blue curve bends right as W declines. In such a case, the fraction to be interdicted would have to increase with declining trafficking to continue the collapse.

Operational Lesson: Even for the baseline model, trafficker flights would not continue to decline if the fraction interdicted also declined with the number of trafficker flights. This could happen if, for example, intelligence gathering or random opportunities to interdict limited the operation because both of these decline with fewer flights. In that case, as the fraction willing declined, the operating point would move down *and significantly to the left.* Eventually, the operating point would fall below the interdiction threshold of the model, and willingness would no longer continue to decline. Worse, there may be another psychological aspect to deterrence – threat of overwhelming intimidation by interdictors versus traffickers becoming emboldened to evolve new methods to shift the balance slightly or overwhelm the interdiction forces. Peru has so far remained in the first condition, but it might break out into the latter if interdiction becomes too lax.

Operational Lesson: Since the fraction interdicted during the Early FD/SD Period greatly exceeded the lethal threshold, the Peruvian result may have been caused by this initial surge of interdictions. Surge operations could be characterized in our model by an exponent significantly larger than 1.0. Thus, we conjectured that the exponent representing deterrence in Peruvian operations was much larger than the theoretical value, 1.150, which is displaced twice the exponent uncertainty range from the best fit. In this case, the lethal threshold could be at or above the value for Post-SJ IV, 0.0154, and yet curve back enough as willingness declines to be consistent with the recent operational periods. This is shown by the red dotted line in Figure IV-13.

Before abandoning the "natural" exponent of 1.0 or values close by, however, we need more independent and corroborating data. As discussed above, there are other ways to explain the value at Post-SJ IV than absorbing it into the model, and we must remember that the uncertainty ranges encompass many plausible alternative patterns.

One promising alternative, which is a topic for future research, is to conjecture that the fraction interdicted is perceived by traffickers to be constant while the number of flights varies more by immediate conditions. This would permit us to calculate the interdiction fraction and willingness on a *monthly* basis. With this, we could reconstruct Figure IV-12 with a monthly trace rather than only sampling operational periods. From this, we might see that the pulses in SJ IV would dance back and forth across the lower threshold for the imprisonment zone. By taking an average fraction interdicted over a few months, we might see Early FD/SD Period become a large surge followed by a gradual decay to a lower steady state with many fewer willing to fly. We might also see

trafficker surges followed by interdiction pulses during more recent post-shoot-down policy periods.

3. Insufficient Wages to Challenge the Shoot-Down Threat

Apparently, very high wages are insufficient to offset the deterrence effect for trafficker pilots. Appendix A analyzes inmate willingness to smuggle against higher risks if their wages were increased. At twice the risk, twice the fee is sufficient, but at three times the risk, four to five times the fee is necessary, and at four times the risk, fees must increase by a factor of about ten. This increase in fees compounds as the perceived risk multiplied by itself – the square of the risk. Thus, pilots discount the face value of money just as do gamblers. Also note that even with greater fees, the total number of pilots enticed into flying reaches a limit well below the level at lower risks.

From anecdotal reports from SJ IV, pilot fees were about $60,000 per flight (Ref. 37). Fees after the shoot-down policy rose to more than $200,000. This was more than a threefold increase in fees, yet few pilots were willing to face the risks of interdiction across the air bridge. There were reports of trafficker organizations under extreme stress offering as much as $1,000,000 per flight without takers.

Appendix A also explains why the inmate respondents implicitly assumed they would receive higher wages when they answered the questions underlying the derivation of the willingness function.

4. Persistence of Deterrence

In December of 1995, 8 months after the effective enforcement of the shoot-down policy, the interdiction forces temporarily stood down. Opportunistically, traffickers immediately flew in relatively large numbers – half the rate prior to the policy. Over the long run, however, restoring the air bridge's capacity requires substantial trafficker investment in clandestine airfields, lining up aircraft and pilots, making connections with a network of buyers and sellers, and providing security including bribes. Such an expansion and investment depends upon trafficker organization perception that the interdiction threat will remain low enough to be "manageable."

Realizing that a substantial and potentially sustainable increase in trafficking over the air bridge would motivate counterdrug forces again to focus a major operation against illicit flights, memories of early 1995 might continue to deter trafficker organizations. Such a persistent effect could continue at reduced levels of interdiction force. However,

trafficking opportunists will continue to attempt to get around the interdiction threat and, if many succeed, the air bridge could rapidly expand, employing these new methods of avoiding interdiction.

For the threat of more intense interdiction effort to remain potent, counterdrug forces must respond to new threats to interdiction effectiveness. Some of these threats are the following:

- Bribery of air interdiction officials – it may be cheaper to pay off the interdictors than to increase pilot fees. Background checks, retrospective analysis of trafficker flights from long-range radar records, and randomizing duty assignments might reduce incentives to take bribes.
- Use of high-tech communications and navigation – encryption, satellite telephones, and GPS navigation aids reduce opportunities to gather intelligence on trafficker flights. Requiring all licit aircraft to carry transponder beacons announcing their position when flying in restricted zones might improve intelligence.
- Filing licit flight plans – blending into the licit traffic works to the extent that counterdrug and air traffic controllers cannot keep pace with the volume of flight plans and traffic. Better administrative coordination with computer networks and retrospective analysis of flights using recorded radar histories could greatly limit this trafficker option.

E. COMMENTS ON THE TAXATION ASSUMPTION

Because it was logical to assume that all interdictions in the source zone consisted entirely of seizures of coca products, illicit chemicals, or eradication of coca plants, it was equally logical to assume that and these production losses merely "taxed" the traffickers with additional overhead.

Deterrence applied to an operational choke point multiplies interdiction efforts many-fold, and produces a non-linear response in the cocaine business. Such operations attack the structure of the coca business rather than just the efficiency of the illicit coca market. Moreover, attacks in the source zone, where the coca products have little value, apply pressure to the links with the least willingness and ability of traffickers to pay high fees. Because each step of the coca flow seems to operate as a separate level of contractors and trafficking organizations, that is, there is little vertical integration, these source-zone trafficking operations effectively cannot tap the higher revenues generated in the United States.

CHAPTER V

IMPACTS ON THE U. S. COCAINE MARKET

V. IMPACTS ON THE U.S. COCAINE MARKET

Chapter III explained the devastating impact on Peruvian coca market and base prices resulting from effective interdiction operations against the air transport routes to Colombia. While source-zone base prices provide an immediate indicator of local impact, they do not address the broader issue of whether cocaine trade to the United States was disrupted. This chapter examines U.S. cocaine prices and purity as well as rates of casual cocaine use to reveal the impact of major source-zone interdiction operations. This resolves the interdictor's dilemma where it ultimately counts, on the streets of the United States.

A. IMPACT ON STREET PRICE AND PURITY

If source-zone interdiction operations are effective, they should create cocaine shortages in the U.S. Shortages should appear as either or both price increases and purity drops at all levels throughout the distribution chain, even down to the street level buyer.

Extracting a meaningful indicator of these price increases from the available price and purity data, however, requires an understanding of the underlying mathematical distributions of the data. These distributions were thoroughly analyzed in a previous IDA report that also provided a time series of street prices with a minimum of statistical uncertainty (Ref. 6). We will extend those time series and give some additional findings from work in progress that analyzes the degree to which source-zone interdiction operations impact prices in the U.S. We will also show the changes in the purity of cocaine bought in the U.S. and discuss these changes as indicators of stress and decline for the cocaine business.

To emphasize that source-zone interdictions had two opposite price effects – depressing prices for coca base in Peru while increasing cocaine prices in the United States – we will also overlay the Peruvian base prices onto the U.S. street price index. This anti-correlation of prices does not make sense economically if one viewed interdictions as only seizing or destroying coca. If only seizure and destruction mattered, Peruvian prices should rise due to the increased demand for the surviving coca. Instead, the severing of the air bridge caused a glut of coca in Peru, which could not reach its

market in Colombia. This depressed prices in Peru while creating a shortage in Colombia and beyond, thus raising prices on the other side of the air bridge.

1. Street Price Index as an Indicator

The previous work at IDA analyzed data from the DEA's System to Retrieve Information from Drug Evidence (STRIDE) (Ref. 20). This database summarizes price and purity for tens of thousands of individual cocaine purchases made by undercover agents since 1981. Because the STRIDE data present statistical and analytical challenges, IDA developed high-resolution methods for extracting meaningful time series. These challenges and methods are described in References 6 and 21, and summarized in this subsection. Some readers may wish to skip this analytical discussion and go to the next subsections, which present our results.

The purity of cocaine sold on the streets of the U.S. varies from a complete swindle (zero purity) on up to more than 90 percent pure cocaine. IDA normalized the price to equivalent pure grams by dividing price by purity. The zero purity purchases were handled as if very low purity to produce a finite number. This procedure will not distort the analysis as explained below.

The purchase volumes vary from 10 kilograms down to 0.01 gram, and there are, of course, deep discounts on price for larger volumes. In fact, the distribution of prices over all volumes after purity normalization has a very long tail extending out to very high prices. The previous IDA work showed that the ordinary "average" of this price is dominated by the minority of high-priced purchases, whether or not zero purity data were included. This implies that the "average" diverges as one collects more data – a very misleading result. Rather than the average, IDA took the median price – the price for which 50 percent of purchases fall above and 50 percent below – as an index of price for across all purchases. We call this the street price index. Note that the zero purity purchases and high-priced purchases simply add more counts to the high side of the median and do not bias the index.

The IDA work shows that the street price index is a well-behaved statistic. Its statistical fluctuations are normally distributed, and bootstrap analysis shows that these fluctuations are much smaller than the price movement features we wish to analyze. Taking the median was shown to be appropriate even over a wide range of volumes, and possible systematic biases caused by variation in purchase volumes were also shown to be insignificant with respect to the price movements owing to operational impacts.

Having understood the statistical uncertainties, IDA formed time series from the medians of the normalized unit price index. That is, we computed the normalized unit price per pure gram for each STRIDE purchase in constant 1992 dollars, and took the median price and median date of each successive 100 samples. There are 451 such groups of 100 samples in our current series ranging from January 1983 through July 1999.

2. Overall Movements of Price and Purity

Figure V-1 shows the street price index time series (blue circles) extended to include more recent data. Two prominent features stand out: the strong decline in prices from 1983 to 1989 followed by fluctuating level prices, and the large reversal to higher prices in 1989-90. The bump in 1989-90 is universally attributed to the many operations associated with Colombian crackdown and the War on Drugs. However, we have seen in Chapter III that this period also included significant, albeit temporary, seizures of trafficker aircraft and the opening of an interdiction airstrip at the Santa Lucia Base (SLB), in the heart of Peru's coca cultivation and trafficking region. The other operations and associated price index features will be discussed in the next subsection.

The cause of the steep and sustained drop in cocaine prices from 1983 to 1989 remains controversial because user consumption was not believed to have fallen this rapidly. The previous IDA paper argued that the loss of monopoly control splintering into many competing producers in Colombia caused the price decline (Ref. 6). A complementary view is that supply caught up with demand as cultivation continued to expand until 1989. Both interpretations are consistent with the simultaneous purity rise from 1983 through 1988. Chapter I, Figure I-4, showed the expansion of coca cultivation, which peaked in 1989. As supply caught up with demand, purity increased and demand grew somewhat more in response.

From 1989 onward, the street price index rose and fell, but never dropped below a floor of about $55 per gram. However, purity appears to have fallen off from 1992 onward. Along with each price rise, there is an even more dramatic purity drop – both features indicate a shortage. Following the enforcement of the force-down/shoot-down policy (FD/SD), price rose and returned, but purity appears to have dropped 10 percent and never recovered.

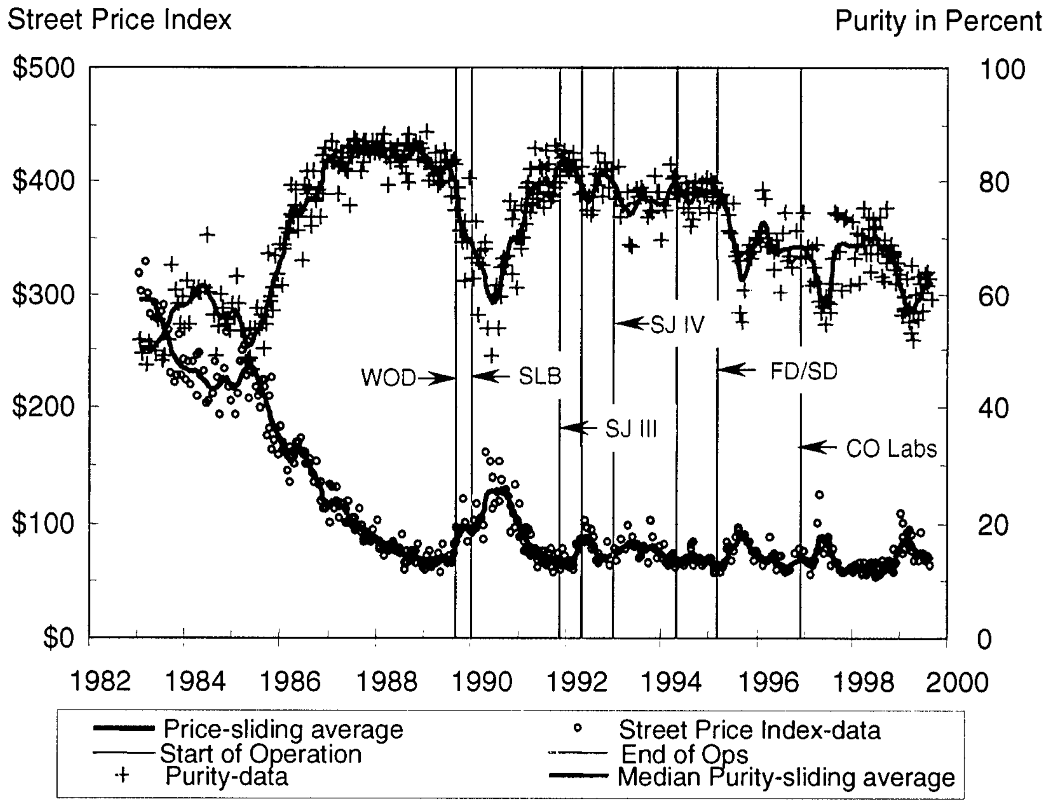


Figure V-1. Price History of the Cocaine Market as Defined by the Street Price Index and Purchased Purity

Ongoing research suggests that purity time series may contain independent information. We believe that in times of shortage traffickers at all levels maintain their revenues in the short term by reducing the purity. This is more pronounced at lower levels in the market with buyers less able to test purity before buying. Nevertheless, we further conjecture that reduced purity is less attractive to the casual users – the source of tomorrow's potential heavy users, and induces a steady decline of cocaine as a drug of choice. If cocaine markets do not recover to previous levels of purity following interruptions of supply, this feature should be analyzed and exploited to support operations. For example, sharp purity drops are evident for several interdiction operations, and preliminary work shows that these drops can be strongly regional. This provides a signature of which trafficker groups were impacted by which operations.

3. Impacts of the Interdiction Operations on the Street Price Index

Figure V-2 provides a more detailed look at the street price index for the U.S. during the 1990's. Vertical lines indicate the beginning of interdiction operations, and

red lines indicate the end of the extended operations, Support Justice III and IV. The FD/SD policy is still in effect.

Overlaid on the street price index are Peru's base prices per kg on a scale to the right. After each operation, Peru's base prices take an immediate and dramatic fall. The street price index, however, only rises several months later. This response to a shock is most pronounced following the raids on major Colombian cocaine processing laboratories in December 1996 and January 1997. Base prices in Peru fell immediately, but it was 4 months later that the street price index rose sharply. Notice that the index went as high as $123/gm, but the sliding average passes below this excursion.[1] Prices in the U.S. began to subside after 6 months and returned to their normal floor in the ninth month. Meanwhile in Peru, coca base prices experienced a minor surge as U.S. prices recovered. This sharp upward excursion of the street price index was isolated in time and clearly indicates the causal connection from source-zone interdiction to U.S. street price excursions.

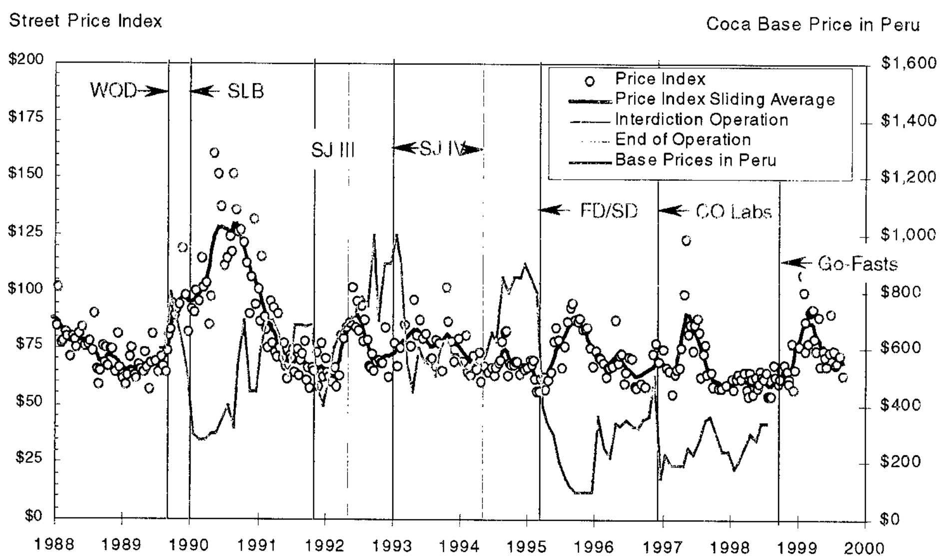


Figure V-2. U.S. Street Price Index, Coca Base Prices in Peru, and Source Zone Interdiction Operations

We have early findings from a time series analysis of the street price index, which is work in progress. Using Auto Regressive Integrated Moving Average (ARIMA)

---

1 The price index sliding average is a triangular weighting function spread over nine successive median values.

modeling methods, we were able to analyze the correlated and delayed responses to source-zone interdictions as seen in the street price index.[2] Essentially, the multiple air interdictions in Peru produced clearly resolved increases of street price index, just as did the attacks on laboratories in Colombia. In all air interdiction cases, the time delays before street prices increased were 5 months.[3] The Colombian laboratory attacks took 4 months to produce a price increase on U.S. streets. Even the most recent 1999 rise in street prices lagged 2 months behind the interdiction operations against what were the principal transshipment routes – the go-fast lanes in the Western Caribbean. These lanes have been virtually closed by those interdiction operations. In each of these cases, the impact on price began to relax starting in the next month. For the interdictions before the FD/SD policy, the characteristic relaxation time for street prices was only 2 months but, after the FD/SD policy, the relaxation took 4.5 months. An equally important finding was that *all* of the visually significant price increases above a floor of approximately $55 per gram were explained by source-zone interdiction operations.

4. Empirical Evidence for a Dynamic Multiplicative Cocaine Market

In Chapter I, Figure I-3, we showed that purchase price increased with sales volume as cocaine passed from one level to the next of the illicit distribution chain. This result is the basis for the multiplicative model of cocaine markets – everyone shares profits and risks, that is, everyone's markup is the same for comparable numbers of sales to customers. What we did not show in Chapter I was that the multiplicative model also holds dynamically for significant price excursions lasting months. The fact that source-

---

2 More sophisticated time series analysis techniques, ARIMA, show that by taking the logarithm of the price series, then taking month-to-month differences in this logarithm, and removing the 28 percent auto-correlation at a one-month lag one obtains a stationary series. Our model represented air interdiction shocks at three levels of intensity: months with one, two and three, or four or more interdictions. Laboratory attacks were modeled as shocks for each month of attack. Finally, the most recent go-fast interdictions were modeled as shocks representing the beginning of these complex operations. Separate classes of interdiction shocks were fit for the interdictions before versus after the FD/SD policy. All of the interdiction shocks were statistically significant, both individually and in combination, except the two classes with only one shoot-down per month. Modeling results were stable whether fitting each class of shocks separately or together.

3 Time lags were independently fit to all five statistically significant air interdiction components of the model. Four or more interdictions in one month for SJ III, SJ IV, and post-FD/SD policy (three components), and all months with two or three interdictions distinguishing before and after the FD/SD policy (2 components). It is exceptionally unlikely that all five of these components would each have a 5-month lag unless there were a common causal mechanism connecting air interdictions with street price excursions upward and subsequent relaxation. Since we examined a 6-month window for each lag, the probability that all five have 5-month lags at random is only $\left(\frac{1}{6}\right)^5 \leq 0.0002$.

zone interdiction events appear as delayed price rises on U.S. streets proves there must be some mechanism to amplify the 18¢ per gram change in base price into an $18 to $50 price rise on U.S. streets as measured by the street price index. The following breakout shows that this end-to-end amplification does take place as a compounding of price markups throughout the levels of the distribution chain.

The STRIDE data provide enough detail to see these co-movements of price for the last two or three levels of distribution. Figure V-3a shows the median normalized unit price calculated for three ranges of purchase volume. Closest to the street are purchases under 10 grams, which are predominantly at the one-gram level. One ounce is the next most dominant transaction volume, and it contains slightly fewer pure grams than its bulk weight of 31 grams. Although purchases above 30 grams include volumes over a kilogram, the majority of the purchases are of a few ounces. Therefore, this third and lowest volume is not a full step up the distribution chain from the others (Ref. 6).

With a compressed time scale, one can see the price excursions more clearly in Figure V-3a. Close examination of the nine-point moving average for the smaller unit price series shows that the actual data rise and fell more than the trend. Nevertheless, these three series appear to all rise following the indicated source-zone operations. Taking the logarithm of price illustrates the near identical nature of these movements as shown in Figure V-3b. A fixed constant percentage change is a constant increment on a logarithmic scale; the small dollar excursions of the small unit price series now appear nearly equal to the excursions of the street sale prices. This was verified using ARIMA modeling to show these series do move in proportion to one another.[4] Similar multiplicative relationships hold in the source zone: leaf, paste, base, and cocaine prices move together.

---

4 Each smaller transaction level was modeled by the level with larger quantity sales. Again, logarithms, differences, and 1-month auto-correlations were modeled to obtain stationary series. All of the parameters of the following models had levels of confidence better than 0.001. The ounce level was modeled by the wholesale level scaled up by 62 percent in price the first month with a 2-month decay thereafter. Similarly, the retail level was modeled by the ounce level scaled up by 87 percent, again with a 2-month decay thereafter.

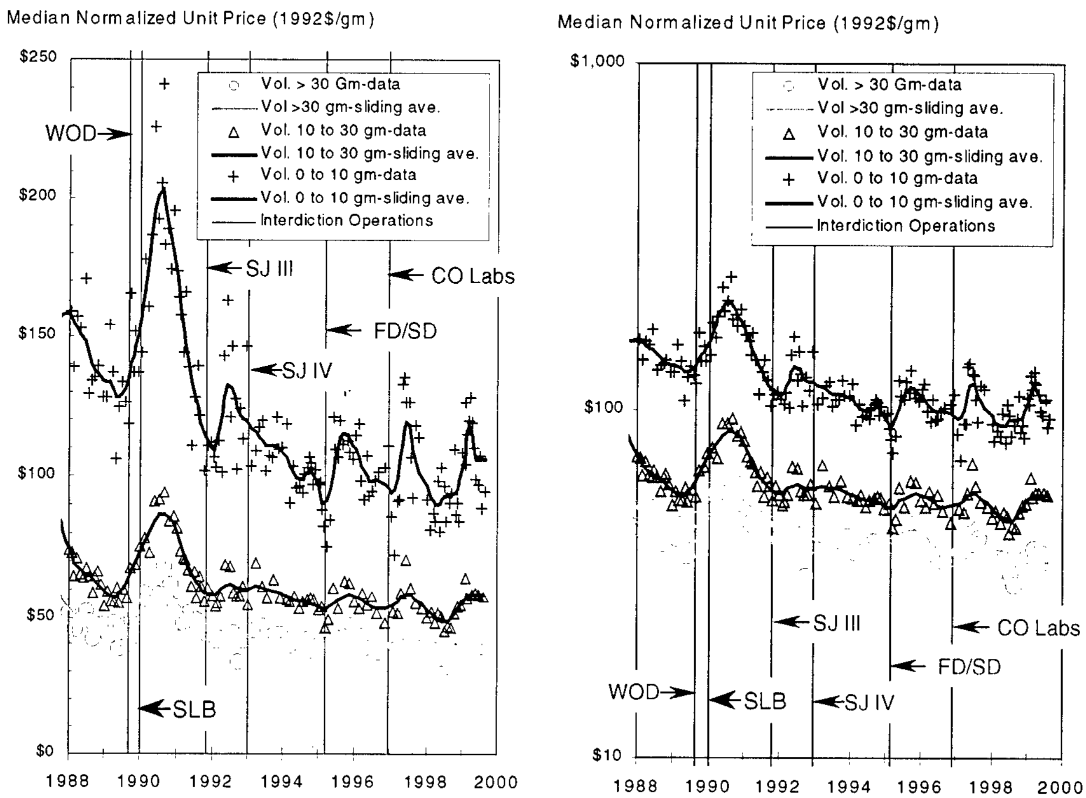


Figure V-3a (linear) and V-3b (semi-log). Median Normalized Unit Prices for Cocaine Purchases at Three Market Distribution Levels

Top: 0 to 10 grams; Middle: 10 to 30 grams; Bottom: 30 grams and larger.

The statistical fluctuations themselves provide empirical evidence for the multiplicative model. One can see by inspection that the vertical scatter of data is greater at higher prices than at lower.[5] This was born out by measurement in creating the ARIMA model.[6] Because the statistical variation of these price series applies to their logarithms, that means they are caused by *random multiplicative factors*. The combined effect of all counterdrug actions from source zone to police on the street creates a random product of price factors. Each level contributes proportionally to the amount of the

---

5 Although there is a 28 percent autocorrelation between logs of monthly price differences, there are no periodic or long-term correlations. Thus, looking at the scatter offers a reasonable impression of the true statistical variation.

6 The scatter of month-to-month differences rose in proportion to the underlying price. This justified taking logarithms before taking month-to-month differences. With this procedure, the differences were comparable for all price levels. Taking logarithms indicates that the underlying impacts leading to statistical fluctuations are multiplicative rather than additive.

transactions they affect. Because flows are extremely concentrated in the source zone, it is no accident that source zone operations produce the most discrete and noticeable swings in the price series. However, all counterdrug activities contribute to this result by sustaining a uniform risk level throughout the distribution chain, which amplifies the source zone increase 100-fold.

5. Refuting the Additive Cost Market Assumption

An $18 per gram movement of U.S. street price index in response to effective interdiction in Peru that caused only an 18¢ per gram price decrease there strongly refutes the additive market assumption of earlier thinking. Although we do not know the detailed price series in Colombia, we do know from sporadic and sometimes inconsistent reports that prices there did not exceed 90¢ of those in Peru during the air interdiction analysis period. Knowing that pilot fees, security costs, and bribes add to trafficker costs during periods of air interdiction, we expect that Colombian prices increased while Peruvian prices decreased. Because Colombia had internal production, we would expect that price increases in Colombia would be less than the price drops in Peru resulting from interdiction pressure on the air bridge. Thus, conservative estimates of upward pressure on source-zone prices would be of order 18¢ per gram. The additive market assumption would claim that an 18¢ per gram increase in base price in the source-zone would have only increased the street price index of $60 to $60.18. Such a small change is clearly inconsistent with the evidence of an $18 or more increase.

B. IMPACT ON CASUAL USERS

We obtained data on the positive test rate for cocaine for a broad spectrum of the American workplace from SmithKline Beecham Clinical Laboratories (SBCL).[7] Typically, they conduct from 250,000 to 300,000 tests per month on workers across the United States. These data have not been accessible to government agencies, and the large monthly samples provide high-resolution information. Because these data represent those in the workplace, the positive test rate reflects use that is more casual rather than those with a seriously debilitating addition. Casual users are important because they are 80 percent of the users and about 20 percent go on to become addicted heavy users, who in turn will consume 80 percent of the cocaine.

---

7 See footnote 35 in the Summary.

Figure V-4 shows the SBCL series overlaid on the street price index. Overall, the SBCL series initially rises, plateaus at about 1.2 percent through 1994 and early 1995, then drops in two steps to the present level of 0.8 percent of those tested. The initial rise is attributed to the growth of the tested population and establishment of testing practices throughout customer base.[8] Features after 1994 represent real nationwide shifts in cocaine use.

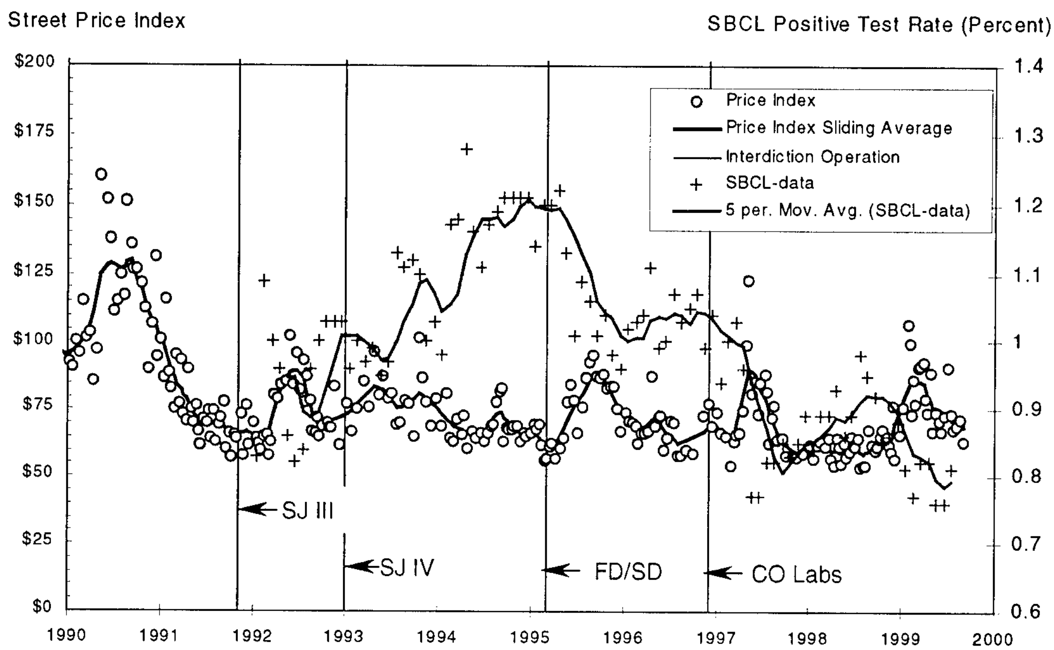


Figure V-4. SmithKline Beecham Clinical Labs Cocaine Positive Test Rate Compared to U.S. Street Price Index and SZ Interdiction Operations

Just following the enforcement of the FD/SD policy, prices began to rise and the SBCL positive test rate began to fall. However, as prices began to relax to $55 per gram, the test rate remained at a level 0.2 percent lower than before. Similarly, after the attacks on the Colombian laboratory complex, positive test rates began to fall and continued to fall until after the price excursion. This fall was again more than 0.2 percent and, subsequently, recovered only 0.1 percent before the next operation at which time the rate fell back to the former lowest level.

8 Modeling of the test process at IDA showed that testing efficiency increased as the frequency of testing and sample size increased.

These falling positive rates indicate reduced cocaine use among those employed in conjunction with transient price increases on the street. Together, these facts suggest a shortage of supply from the source zone. They also suggest that major source-zone operations catalyze persistent decrements in casual usage. This is very non-linear behavior. Responses are not simply in proportion to "causes" such as a spring being compressed and released. Rather, changes persist indicating that irreversible damage had taken place.

Combined with other examples given in IDA's pervious work, these time series consistently and repeatedly show evidence of damage or decline in the cocaine business following major source-zone interdiction operations. These indicators of damage resolve the final issue of the interdictor's dilemma – yes, source-zone interdiction does lead to significant decline in the cocaine business as measured within the United States.

CHAPTER VI

AN INTERDICTION STRATEGY FOR COLOMBIA

VI. AN INTERDICTION STRATEGY FOR COLOMBIA

This final chapter is neither a summary nor a bottom line; rather, it is an outline of an interdiction strategy to counter cocaine trafficking and a speculative survey of current issues arising from Colombia.

Today, the primary source-zone cocaine-related interdiction issue is how to curtail Colombia's expanding cocaine industry. On the ground, two insurgencies – the Fuerzas Armada Revolucionarias de Colombia (FARC) and the Ejercito de Liberacion Nacional (ELN) – and many paramilitary militias control or terrorize large portions of the country. Trafficker' revenues and violence continue to have corrupting and intimidating influences on citizens and officials. And cocaine sales bring in millions of dollars that fund a great portion of the weaponry for these extra-legal and violent organizations.

The potential promise of the air interdiction strategy is to deny traffickers much of the profit from marketing coca products. Traffickers may not have a viable alternative transportation option, and if they manage to develop riverine or overland modes, these more difficult and risky avenues will absorb most of their profits. Air interdiction operations become more effective as the growing areas continue to concentrate. Either before or after processing base to cocaine, traffickers will have to fly the majority of their product out of the growing areas. In principle, a relatively modest Colombian Air Force, well supported by USG intelligence gathering assistance, could interdict a sufficient number of smuggler pilots to deter their flying, and deny traffickers their needed air transportation. We begin this chapter with a section outlining an overall interdiction strategy for Colombia that embodies the lessons from Peru.

Air interdiction, however, is only a key element of an integrated strategy. Even if successful, it only renders the situation less violent and more amenable to reestablishing a national unity to further diminish the cocaine business. Standing against this potential promise of air interdiction are three sets of considerations. First is a set of assumptions about the Colombian government and the shared national will. Second is a set of concerns over the ability of traffickers and their protectors to consolidate their power and resources either vertically or horizontally. Third is a set of practical support needs to implement the strategy.

A. OUTLINE OF AN INTERDICTION STRATEGY FOR COLOMBIA

Here we apply the lessons from our analysis of operations in Peru to outline a conceptual interdiction strategy to dismember the cocaine business in Colombia. The following sequence begins with operations against the most vulnerable and lucrative targets. It sustains and follows up with continued pressure on traffickers, but it puts only economic pressure on the bulk of the peasant labor supporting the cocaine business:

1. The most vulnerable interdiction links are the transport vectors into and out of the cocaine production laboratories. Large cargoes of highly valuable coca product are essential if traffickers are to coordinate multi-ton movements in an insecure environment. Similar reasoning suggests that the transport of cash for payment in these large transactions is equally vulnerable. To effectively attack trafficker air routes, Colombia will have to establish tight air traffic control over both licit and illicit flights.

2. Attacks on secondary transport modes and routes would keep pressure on the traffickers' critical links for coca base, cocaine, and possibly chemicals. Mapping these transport modes and routes also provides intelligence on the supply system for essential bulk chemicals and the location of major cocaine laboratory complexes. Investigating the financial institutions and dollar flows in the cocaine production regions also promises to reveal the critical nodes and trafficker organizations.

3. Follow-up raids on chemical supply points and major laboratory complexes would add to the uncertainties and inefficiencies of the cocaine business further reducing profits. Note that attempts by traffickers to disperse cultivation or cocaine laboratory operations only worsen their on-the-ground security problems and undermine processing efficiency.

4. Disruption of transport routes and modes causes traffickers to seek new routes and modes generally operated by unfamiliar groups of contractor smugglers. This creates an opportunity for sting operations. Further down the distribution chain, frequent system-wide supply shortages cause middlemen to seek new suppliers, which strains transaction negotiations already burdened by lack of trust.

5. As coca base prices fall due to these operations against coca markets, several follow up strategies become feasible. First, the guerrillas and paramilitaries would have less money for arms and mercenaries, which strengthens the elected government's position in negotiating a meaningful peace. Second, low coca prices lead to crop abandonment while alternative development programs support eradication of abandoned coca plants. Because these coca crops take more than 1 year to replace, this helps lock in the reduction of the scale of coca cultivation.

Continued forced eradication may be effective in the Guaviare region, but is high-risk and possibly counter-productive in the Putumayo or Caqueta regions. The Guaviare cultivation of lowland coca is already at an efficiency disadvantage since it competes with the rapidly growing Putumayo and Caqueta regions for labor, and previous forced eradication caused spatial dispersion of dense areas, further reducing efficiency. However, the risks of ground fire against eradication spray aircraft and the resentment of farm labor against the elected government may not be worth the modest "tax" that forced eradication could extract if extended to the Putumayo or Caqueta regions. Furthermore, aerial eradication requires large-scale operation over much of the cultivation region while air interdiction only need engage relatively few undefended aircraft.

B. ASSUMPTIONS ABOUT COLOMBIAN SUPPORT

Since the USG only supports the Source-Zone country in their efforts to reduce cocaine trafficking, the host country's leadership and national will is a precondition for all operations. Specific to air interdictions, we must assume the following support will be sustained:

- Effective means to prevent the corrupting influence of bribes and intimidation from undermining interdiction plans and operations
- Courts that will imprison any traffickers who submit to inspection by air interdiction forces rather than being shot down
- Alternative development and other forms of economic support to offset the loss of coca revenues and the burden on a disrupted economy from engaging conflict on several fronts without benefit of illicit proceeds from coca
- Commitment to rid Colombia of the cocaine business with its corruption and violence.

C. THE THREAT OF TRAFFICKER CONSOLIDATION

At present, the map of Colombia is dotted with areas outside of government control where paramilitary forces or insurgency groups hold real power or exert influence. Fortunately, these many groups, who protect and tax the cocaine business activities, are as yet unconsolidated. This greatly reduces their transportation options, the sophistication of their methods, and their direct revenues, while keeping their security costs high (protecting themselves from other extra-legals as well as from the government).

A bit of speculation about the possibilities that open up for trafficker organizations if they could consolidate by horizontal integration illustrates the importance of preventing horizontal organization:

- Greatly reduced inter-faction security costs in many contested areas and over cocaine production assets and transportation routes.
- Consolidated agreements across national boundaries with outside groups or bordering nations for supplies, safe havens, and routes to smuggle cocaine.
- Pooled buying of high-tech equipment and training in communications, security, and possibly air defense.
- Improved agricultural practices and processing efficiencies in cocaine production.
- Vertical expansion into new markets or encroachment on established ones to increase revenues.

Working to prevent horizontal integration or even cooperation among traffickers are their longstanding hostilities towards one another, which have created the lawless environment in which the cocaine business flourishes. Because many Colombians are enraged by the violence, they may opt for any peace they can get, including one that tolerates an illicit but less violent drug trade. This observation contains a warning: if hostilities lessen through some form of détente among the warring parties, the resulting more integrated coalition must not be allowed to traffic in cocaine at reduced risk. We do not want to see traffickers learning to cooperate before the political factions agree to restoring the full rule of law, including the elimination of the cocaine trade.

Now, let us consider the options for vertical integration. Although large trafficker organizations may be able to promote cocaine use in new markets, it is unlikely they can tap much of the revenue within established distribution systems. The multiplicative model implies that mobility from one level or place in the distribution system to another does not *on average* create an opportunity for more return on investment. If a vacuum forms, neighboring traffickers will move in. But, unless a trafficker is willing to take risks for less reward than their peers, there is little revenue to be skimmed off to a different level of the market.

D. PRACTICAL REQUIREMENTS OF IMPLEMENTATION

Colombia's operational environment does not offer the support to air interdictors that was available in Peru. Serious obstacles include the following:

- For many years in Peru, alternative development workers and other researchers could gather coca prices in key regions. In Colombia, conditions are much less safe, and we doubt that consistent diverse price data are being collected.
- Interdiction forces need bases for radars, interceptors, and intelligence gathering. Within Colombia, a major government base at Mira Flores has been overrun by the FARC. This threat means either that bases must be larger in order to be able to defend themselves, or that the central government must be willing and able to protect bases with mobile forces.
- New technology and the polarization of the warring groups reduces access to operational intelligence to support air interdiction. Technological advances in communications and navigation reduce the opportunities for intercepting useful signals, and the polarization of the population probably makes informal information sharing even more dangerous than it was in Peru.

Nevertheless, the air interdiction operational lessons from Peru still hold the best promise for reducing the profitability of the cocaine industry in Colombia. Price information should be available from many sources, and a coordinated strategy should be able to collect useful data. With USG support and training, vetted Colombian forces could create and hold bases in strategic locations. And location reporting devices required on all aircraft flying in restricted areas, computer networks, and enhanced detection and monitoring methods should be able to create a more coherent air picture over the growing regions. Even retrospective information could be useful in court to prove illicit movement not reported on filed flight plans. Air interdiction of coca trafficking flights remains the best option for reducing the profitability of the cocaine business, reducing the money going toward violence and corruption, and inducing the parties to take the next steps toward restoring order in Colombia.

REFERENCES

1. UNODCCP. Global Illicit Drug Trends. United Nations Office for Drug Control and Crime Prevention, Studies on Drugs and Crime, New York, 1999.

2. Reuter, Peter and Mark Kleiman. "Risks and Prices: An Economic Analysis of Drug Enforcement." *Crime and Justice*, an annual Review of Research, edited by Michael Tonry and Norvel Morris, University of Chicago Press, Vol 7, 1986.

3. Riley, Kevin Jack. *Snow Job? The War Against International Cocaine Trafficking*. New Brunswick, New Jersey: Transaction Publishers, 1996.

4. Berry, Brian J. L., and Frank Horton. *Geographic Perspectives on Urban Systems with Integrated Readings*. Prentice-Hall, Inc, 1970.

5. CNC. "Colombia: 1999 Coca Estimates." Briefing from Crime and Narcotics Center of the CIA annual estimates from 1996 through 1999, released in February of the following year along with density profile maps of the growing regions.

   CNC. "Peru: 1999 Coca Estimates." Briefing from Crime and Narcotics Center of the CIA annual estimates from 1996 through 1999, released in February of the following year along with density profile maps of the growing regions.

   CNC. "Bolivia: 1999 Coca Estimates." Briefing from Crime and Narcotics Center of the CIA annual estimates from 1996 through 1999, released in February of the following year along with density profile maps of the growing regions.

6. Crane, B., Rivolo, A.R., and Comfort, G. *An Empirical Examination of Counterdrug Interdiction Program Effectiveness*. Alexandria, Virginia: Institute for Defense Analyses (IDA), P-3219, January 1997.

7. Caulkins, Johnathan and Rema Padman. "Quantity Discounts and Quality Permia for Illicit Drugs." *Journal of the American Statistical Association*, Vol. 88, No 423, Applications and Case Studies, September 1993.

8. Caulkins, Johnathan. "Modeling the Domestic Distribution Network for Illicit Drugs." *Management Science*, Vol. 43, No. 10, October 1997.

9. Bureau of Justice Statistics (BJS), Office of Justice Programs, U.S. Department of Justice. *Drugs, Crime, and the Justice System: A National Report*. Washington, DC: BJS, December 1992.

10. Rockwell International Special Investigations Inc. "Measuring Deterrence – Approach and Methodology." Component I Study Report by Decision-Science Applications Summer Associates. October 1989.

11. Starr, Chauncy. "Benefit-Cost Studies in Sociotechnical Systems." *Perspectives on Benefit-Risk Decision Making*, National Academy of Engineering, Washington, D.C., 1972.

12. Crane, Barry, Steve Warner, and Melissa Kuchma. *Fisheries Law Enforcement: Assessment of Deterrence*. Alexandria, Virginia: Institute for Defense Analyses (IDA), D-2381, January 1997.

13. Luce, Duncan R. and Elke U. Weber. "An Axiomatic Theory of Conjoint, Expected Risk." *Journal of Mathematical Psychology*, 30, 188-205, 1986.

14. Weber, Elke. "The Utility of Measuring and Modeling Perceived Risk." *Choice, Decision, and Measurement: Essays in Honor of R. Duncan Luce*. A.A. J. Marley editor, Lawrence Erlbaum Associates, Publishers, New Jersey and London, 1997.

15. Stevens, S.S. Psychophysics: Introduction to Its Perceptual, Neural, and Social Prospects. John Wiley & Sons, 1975.

16. Crane, Barry. *Deterrence Effects of Operation Frontier Shield*, Institute for Defense Analyses, IDA Paper P-3460, March 1999.

17. DEA. Operation BREAKTHROUGH: Coca Cultivation and Cocaine Base Production in Peru. Intelligence Division, DEA-97010, June 1997.

18. Cuanto SA. Coca's Impact in Peruvian Economy, Peru 1980-1992, Methodological Appendix. Lima, Peru: September 1993.

19. Nunez, J. and R. Reategui. La Economia Cocalera en el Alto Huallaga: Impacto Economico. Tesis de Bachiller. Lima, Peru: Universidad del Pacifico, 1990.

20. DEA, 1994-1999, Drug Enforcement Administration, System to Retrieve Information from Drug Evidence (STRIDE), Deputy Administrator for Intelligence, Statistics Division. Monthly updates provided as private communication.

21. Rivolo, Rex A., Barry Crane, and Gary Comfort. "Structure and Dynamics of the Cocaine Market." A briefing to the National Research Council, Committee on Data and Research for Policy on Illegal Drugs, June 1998.

22. Crane, Barry. *Current Operational Assessment and Progress Toward a Columbian Engagement*, Institute for Defense Analyses, IDA Document D-2407, November 1999

23. *El Tiempo*, Bogotá, Colombia, 20 December 1999

24. Narcotics Affairs Section (NAS/Peru). Estimates of Economic Impact of Coca and Coca By-Products Production – Part I. Lima, Peru: July 9, 1992.

25. Natarajan, Mangai. Understanding the Structure of Drug Trafficking Organization: A Conversational Analysis. Presented to the National Research Council, Committee on Data and Research for Policy on Illegal Drugs, 19-20 May 1999.

26. UNDCP. Monthly Price Reports. Lima, Peru.

27. Laity, Jim. The Coca Economy in the Upper Huallaga. Lima, Peru: July 1989.

28. Tropical Research and Development, Inc. Lessons Learned Evaluation. Upper Huallaga Area Development Project. 527-0244. September 19, 1992.

29. GAPA. Peru: Estadisticas de Superficie, Produccion y Precio de 175 Cultivos Segun Regiones Naturales: 1964-84. Lima. Estudios Agronomicos No 5, PADI. 1988.

30. CNC. "Colombian Coca Yields: An Update." *Crime and Narcotics Center of the CIA*, CN 99-40010, February 1999.

31. Page, Jason A. "Coca Fact Paper: A Primer." CNC, May 1995.

32. DEA. Operation BREAKTHROUGH: Coca Cultivation and Cocaine Base Production in Bolivia. Intelligence Division, DEA-94032, July 1994.

33. *Andean Report (AR)*. "United Nations Agronomists Fear That Soil Fungus Blight Could Botch Substitute Crop Projects in the Upper Huallaga Valley." June 1991 (85).

34. Gonzales, J.E. "Guerrillas and Coca in the Upper Huallaga Valley," *The Shining Path of Peru*, 2nd ed. Ed. D.S. Palmer, pp. 123-43: New York: St. Martin's Press, 1994.

35. Batty, Michael, and Paul Longley. *Fractal Cities: A Geometry of Form and Function*. Academic Press, 1994.

36. Joint Chiefs of Staff. Department of Defense Dictionary of Military and Associated Terms. Joint Publication, 1-02, on-line and continuously updated.

37. USAID/Peru (AID). Peru's Cocaine Economy: Estimates of the Economic Impact of Peru's Cocaine Industry in 1992. Lima, Peru: October 1993.

38. de Rementeria, Iban. "Evolucion en el Peru de los precios de la hoja la coca y sus derivados entre 1989 y 1992." The Peru Report. Lima, Peru: July 1992.

39. U.S. Embassy Peru, Economics Section. Peruvian Economic Indicators: 1992-1995. Lima, Peru: May 15, 1995.

40. Accion Agraria. Final Report: Evaluation of the Upper Huallaga Area Development Project 527-0244. Lima, Peru, December 1994.

41. Arevalo, Enrique. Analysis Economico de la Produccion de Hoja Seca de Coca. Universidad Nacional Agraria de la Selva (UNAS), Tingo Maria, Peru, 1996.

42. Lee, Rensselaer. *The White Labyrinth: Cocaine and Political Power*. New Brunswick, New Jersey: Transaction Publishers, 1989.

43. Clawson, Patrick and Rensselaer Lee. *The Andean Cocaine Industry*. New York: St. Martin's Press, 1996.

44. Treaster, Joseph. "Colombia Turns Drug War Into a Long Chase." *The New York Times International*. November 10, 1989 (A10).

45. U.S. Senate (Senate). Committee on Governmental Affairs, Permanent Subcommittee on Investigations. Structure of International Drug Trafficking Organizations. Washington, DC: September 12, 13, 1989.

46. U.S. House of Representatives (House). Committee on Government Operations. Stopping the Flood of Cocaine with Operation Snowcap: Is it Working? Washington, DC: August 14, 1990.

47. U.S. Drug Enforcement Administration (DEA). *Coca Cultivation and Cocaine Processing*. Washington, DC: September 1993.

48. Associated Press (AP). "Colombian Presidential Candidate is Slain at Rally." *The New York Times International*. August 19, 1989 (3).

49. Reuters. "Colombian Crackdown Intensified." *The New York Times*. August 22, 1989 (A1).

50. Treaster, Joseph. "Colombians Seize Two Drug Figures." *The New York Times*. August 26, 1989 (5).

51. Weinraub, Bernard. "President Offers Strategy for U.S. on Drug Control." *The New York Times*. September 6, 1989 (A1).

52. Wines, Michael. "Influx of Cocaine in U.S. Has Slowed, Drug Officials Say: Colombia Assault Cited." *The New York Times*. September 9, 1989 (1).

53. U.S. House of Representatives (House). Committee on Government Operations. United States Anti-Narcotics Activities in the Andean Region. Washington, DC: November 30, 1990.

54. *Drug Trafficking Update* (DTU). "The U.S. Doesn't Play by the Same Rules." September 1990 (4).

55. Isikoff, Michael. "Next Leader Says Colombians Expect 'Sanctions' Against Barry." *The Washington Post*. July 14, 1990 (A10).

56. Farah, Douglas. "Colombia Offers Drug Lords a Deal." *The Washington Post*. September 7, 1990 (A17).

57. U.S. Department of State. International Narcotics and Control Strategy Report (INCSR). Washington, DC: March 1997 (and years going back to 1986).

58. Farah, Douglas. "Colombia's President Denies Pact With Drug Lords." *The Washington Post*. December 22, 1990 (A8).

59. Clayton, Mark and Stan Yarbro. "Gaviria Brings Hope to Colombia." *Christian Science Monitor*. July 24, 1991.

60. Stevenson, Sharon. "Peru Farmers Blame U.S. for Blight on Coca." *The Miami Herald*. June 2, 1991 (1A).

61. National Narcotics Intelligence Consumers Committee (NNICC). The NNICC Report 1995: The Supply of Illicit Drugs to the United States. August 1996 (and years going back to 1978).

62. Treaster, Joseph. "War on Cocaine in Peru Is Sputtering." *The New York Times International*. October 23, 1989.

63. *Drug Trafficking Update* (DTU). "Hands Up, Prices Down." August 14, 1990 (1).

64. Farah, Douglas. "Colombia Split on Continuing Anti-Drug War." *The Washington Post*. September 21, 1989 (A35).

65. Gugliotta, Guy. "Drug Wars–Hey, We're Winning! Bush's Message in Cartagena Should Be That the Cocaine Crackdown Works." *The Washington Post*. February 11, 1990 (C1).

66. Greve, Frank. "Coca-leaf price plunge is good news for DEA." *The Miami Herald*. June 29, 1990 (14A).

67. Dillon, Sam. "Coca-Leaf Price Collapses to All-Time Low in Andes." *The Miami Herald*. August 14, 1990 (18A).

68. *Drug Trafficking Update* (DTU). Comision Andina de Juristas. "Operation Apocalypse II." May 7, 1990 (4).

69. Yarbo, Stan. "Andes Nations Face Drug War Travail." *Oregonian*. February 11, 1990 (A11).

70. Yarbo, Stan. "Cocaine Trade Shifts in Colombia." *Christian Science Monitor*. June 3, 1991.

71. USAID/Peru (AID). Inter-office memorandum. "UHV Facts and Figures." July 18, 1991.

72. Treaster, Joseph. "Drug War Stalled in Two Key Countries." *The New York Times International*. December 6, 1989.

73. U.S. General Accounting Office (GAO). Drug Control: Expanded Military Surveillance Not Justified by Measurable Goals or Results. Washington, DC: October 5, 1993.

74. U.S. Senate (Senate). Committee on Foreign Relations, Subcommittee on Terrorism, Narcotics, and International Operations. Andean Drug Initiative. Washington, DC: February 20, 1992.

75. PaceCom Incorporated. Interview with Director of Narcotics Affairs Section of U.S. Embassy Peru. Lima, Peru: July 1996.

76. Nash, Nathaniel. "U.S. Says a C-130 Was Hit by Gunfire From Peru." *The New York Times International*. April 25, 1992 (L5).

77. Associated Press (AP). "U.S. Pulls Radar Out of Peru." *The Miami Herald*. May 14, 1992 (18A).

78. Schmidt-Lynch. "U.S. Radar Tracks Drug Traffickers' Flights Over Peru." *Washington Post*. February 18, 1993.

79. Instituto de Analisis de Politica Agraria (IAPA). Technical, Economic and Social Soundness Analysis: Counternarcotics Sustainable Development Project AID/Peru. Draft Report. Lima, Peru: November 1994.

80. Reyes, Francisco. "Peru's Deadly Drug Habit Behind the Fujimori Front, Corruption and Cocaine Trafficking Are Booming." *The Washington Post*. February 28, 1993 (C4).

81. Associated Press (AP). "U.S. Withdraws Advisers." *The New York Times International.* April 15, 1992 (A12).

82. Dillon, Sam. "Dark Past of Peru's Drug Czar." *The Miami Herald.* May 30, 1992 (1A).

83. El Comercio. "General Bellido Mora sabia del cobro de cupos." July 31, 1996

84. Trujillo, Stephen. "Peru's Maoist Drug Dealers." *The New York Times.* April 8, 1992 (OP-ED).

85. Brooke, James. "Peru Suspends Democracy, Citing Revolt." *The New York Times.* April 7, 1992 (A1).

86. USAID/Peru (AID). Andean Counter-Drug Initiative, Objective IV: Alternative Development, Semi-Annual Report, October 1992-March 1993. Lima, Peru: May 1993.

87. U.S. General Accounting Office (GAO). Drug Control in Peru. Washington, DC: August 16, 1994.

88. Brooke, James. "High Cost of Fighting Drugs Strains U.S.-Colombian Ties." *The New York Times.* June 4, 1994 (D1).

89. USAID/Peru (AID). Inter-office memorandum, "June Coca data." July 23, 1993.

90. Trujillo, Stephen. "Corruption and Cocaine in Peru." *The New York Times.* April 7, 1992 (OP-ED).

91. Narcotics Affairs Section (NAS/Peru). INCSR Submission. Lima, Peru: January 1988.

92. Lemieux, Josh. "Due Process? U.S. helps shoot down suspected drug planes." *The Miami Herald.* September 26, 1995 (1A).

93. Johnson, Tim. "Colombia, Peru Downing Drug Planes." *The Miami Herald.* August 7, 1995 (6A).

94. Fineman, Mark and Craig Pyes. "Cocaine Traffic to U.S. Finds Holes in High-Tech 'Fence.'" *Los Angeles Times.* June 9, 1996 (A1).

95. Bowen, Sally. "Peru Shifts to Battling Drugs Instead of Rebels." *Christian Science Monitor.* April 28, 1995 (6).

96. Craig, James. "Market Has Slipped, but Farmers Find It Hard To Stop Growing Coca." *The Washington Times.* September 15, 1995.

97. Prisma, A.B. PL480 Title II Program in the Apurimac River Valley. Lima, Peru: 1996.

98. PaceCom Incorporated. *Latin Shoot-Down Policy Disrupts Coca Paste Flights.* Drug Enforcement Report. September 8, 1995 (3).

99. U.S. Drug Enforcement Administration (DEA). The South American Cocaine Trade: An "Industry" in Transition. *Intelligence Bulletin.* Washington, D.C.: June 1996

100. *Expreso*. "Peru: New Routes to Smuggle Cocaine Base into Ecuador Discovered." October 25, 1996

101. Carter, Thomas. "Drug Agencies Want Surveillance by U.S. Resumed." Washington Post, page A15, November 4, 1999.

102. U.S. Drug Enforcement Administration (DEA). Price and Purity Reports, 1987-1993.

103. Bell, David E., Howard Raiffa, and Amos Tversky. *Decision Making: Descriptive, Normative, and Prescriptive Interactions*. Cambridge University Press (p.9-30), 1991.

APPENDIX A

THE DETERRENCE MODEL

APPENDIX A
THE DETERRENCE MODEL

Cocaine smuggling is a high-risk activity. Even though some smugglers might be attracted by risk or desperate for the quick profits, one would expect that, as the chances of being caught, imprisoned, or killed increase, many would quit smuggling. We address the following questions in this appendix:

- What is the level of risk necessary to deter most smugglers?
- If smugglers can be deterred, can we predict their behavior as a group with a mathematical model?
- How do smugglers differ from the traffickers who only own the drugs being smuggled, and can traffickers somehow compensate smugglers enough to take very large risks?

These questions could be addressed in several ways: directly, by examining interdiction operations at different levels of risk; indirectly, by examining the literature on risk taking; or subjectively, by interviewing captured smugglers. We have data for only a few operations, which might be confounded by other factors that distort the purely deterrent aspects. Nevertheless, we can compare these known operations with a model once it has been developed. Although, the literature provides some clues to the form of a deterrence model, it is not sufficient to build a useful mathematical model of the behavior of a large group of smugglers. While interviews with imprisoned smugglers seem liable to bias, prisoners serving long prison terms apparently want to share their knowledge – bragging rights if you will – if they can do so without self-incrimination or adding to their prison time. Although interview data represent only the opinions of smugglers, such *opinions* are the ultimate basis of deterrence. Fortunately, there are interview data with sufficient detail to build a mathematical model of deterrence. The interview data also address other factors influencing a smuggler's behavior, such as the effectiveness of compensation to offset risks.

The U.S. Customs Service sponsored a team to interview confidentially 112 former drug smugglers in federal prisons concerning the conditions under which they would be willing to continue various illicit activities (Ref. 10). Data from these interviews led to our mathematical model of deterrence for various degrees of

interdiction risk. We will show that interview results were remarkably useful – determining the mathematical form of the equation and calibrating its coefficients as a model for the willingness to attempt to smuggle against various chances and consequences of failure.

Although the interviews are our principal source of information for building a model, the literature on risk taking helps corroborate the mathematical form of the model's equation. After deriving the interdiction model, we compare transit-zone and source-zone operations with our deterrence model and show that actual operations agree with this model. Finally, we explore a variety of related topics such as willingness to smuggle against greater risk for greater compensation, and losses necessary to cause smugglers or owners of drugs to change locations, methods, or quit.

A. A CONCEPTUAL MODEL OF THWARTING SMUGGLERS

An empirically valid mathematical model of deterrence could provide a basis for planning operations by predicting the level of interdiction necessary to achieve a pre-selected level of reduction in trafficking. The model would translate the desired level of interdiction into the size of the interdiction force and its necessary level of endgame threat, that is, consequences for the interdicted smugglers. A valid model would also enable us to learn from real operations and calibrate smuggler responses more precisely to refine future interdiction efforts.

Smuggling success depends upon both the willingness to attempt to smuggle and, if attempted, the ability to avoid interdiction. Thus, conceptually, the probability of a smuggler being thwarted can be expressed mathematically as follows:

$$P_t = 1 - (1 - P_I) \cdot W(P_I) \qquad (1)$$

Here, P_t is the probability of being thwarted, i.e., being deterred or interdicted; P_I is the probability of being interdicted if a smuggling attempt is made; and $W(P_I)$ is the probability that the smuggler would be willing to make an attempt if the risk of interdiction were P_I.

Equation (1) assumes that smugglers' perceptions of the probability of interdiction are equal to (or at least proportional to) the actual probability of interdiction. If information was slow to reach most of the smugglers or they were slow to adjust their activities based on new information, real risks might differ from perceived risks or behavior. For example, during the early months of U.S. support to the Peruvian force-down, shoot-down (FD/SD) policy, smuggler pilots might not have believed that

interdiction forces would be as effective as they continued to be; had they realized what they were up against, they might have stopped flying earlier. Since we can make later adjustments for lags in perception by observing smuggler responses to any real operation, we assume for mathematical simplicity that the perceived risks equal the actual current risks. Most of our modeling effort focuses on deriving a calibrated expression for the unknown function, $W(P_I)$, representing the smugglers' willingness to smuggle against different levels of interdiction threat. Once we have $W(P_I)$, we can complete the model with equation (1).

B. INTERVIEWS WITH INCARCERATED SMUGGLERS

The interview research team contacted the U.S. Bureau of Prisons and selected inmates whose offense code identified them as currently serving time for violation of pertinent sections of the Drug Abuse Prevention Control Act of 1970. The research team selected a sample of inmates from nine federal prisons in five states and one state prison in Texas.

1. Credibility of the Interview Responses

To avoid selection biases, no discriminations were made on weight or type of narcotic, arresting agency or location of arrest, length of sentence, age, sex, or demographic profile. Prior to the interviews, inmates were told their answers would be kept in confidence and the information they gave could not be traced to them. Nearly half of the sample of inmates with drug convictions agreed to participate, yielding a final sample size of 112.

Responding inmate smugglers were quite diverse demographically and by level of experience:

- Their ages ranged between 20 and 50 years.
- Half were U.S. citizens, while the rest were distributed equally among Mexican, Colombian, and other nationalities.
- They split equally among high school dropout, high school graduate, and college educated – some had Ph.D.'s.
- Half had smuggled marijuana, 40 percent cocaine, and 10 percent heroine. Some smuggled more than one drug or other types of drugs. Because the data were aggregated, we cannot be certain that the cocaine smugglers' responses were distributed similarly to the other smugglers. However, the eventual consistency and uniformity of the results tends to justify combining the data.

- Their experience smuggling was almost uniformly distributed from 1 to 10 times, averaging about 6 times overall.

Interviewers were selected for their investigative expertise, bilingual capability, law enforcement background, and drug interdiction experience. Their combined experience minimized frivolous answers. Interviewers commented that the variety of inmate respondents and the commonality of their responses indicate there were no identifiable biases.

The interviewers asked the inmates to answer questions from two separate points of view. The first point of view, "self," contained the responses of inmates about their own actions, perspectives, and future smuggling intentions. The second point of view, "Associate," contained similar responses but from the perspective of a former associate or friend in the smuggling business. Some of the survey respondents commented that, in retrospect from prison, they had underestimated the chance of being caught. Some inmates went so far as to suggest that the government conduct a campaign of informing currently active smugglers. This led the interviewers to conclude that the answers as "associate" were more likely to be representative of the majority of active smugglers.

2. Responses on Willingness to Smuggle

Three principal questions comprised the data that became the framework for our mathematical model of the willingness to smuggle. These questions were of a common form.

> "I would not smuggle drugs into the United States if my chances of getting caught [caught and convicted, or caught, convicted, and imprisoned] were: A. 1 in 10 times, B. 1 in 5 times, C. 2 in 5 times, D. 4 in 5 times, or E. Every time."

Inmates were then asked to choose from one of the five degrees of risk.

Table A-1 shows the responses to these three questions for "self" and "associate." Note that most inmates answered most questions. Note that the responses in each of these probability-of-interdiction categories represent those who would be deterred by the selected level of risk but not deterred by lower levels of risk. Thus, someone not willing to smuggle against the chances of "2 in 5 times" of being caught might actually be unwilling if the chance were only slightly greater than the previous category, "1 in 5 times." Statistical analysis of data grouped into categories such as these require special analytical techniques, as described in Appendix B.

Table A-1. Additional Number of Inmates *Not* Willing to Smuggle as Risk Increases

	Imprisoned		Convicted		Caught	
Probability of Interdiction	Self	Associate	Self	Associate	Self	Associate
1 in 10	83	43	72	32	63	21
1 in 5	11	27	16	25	17	29
2 in 5	5	13	9	26	15	25
4 in 5	2	3	4	5	3	3
Every Time	3	6	3	4	6	14
Respondents	104	92	104	92	104	92
No Answer	5	0	5	0	5	0

To analyze grouped data and later assist in visualizing trends without interference from arbitrary choices of probability cut-offs used in the interview questions, we computed the *cumulative* percentages of those willing to smuggle against various odds of being interdicted. These percentages are shown in Table A-2.

Table A-2. Cumulative Percentage of Those Willing to Smuggle at a Risk Greater than or Equal to the Probability of Interdiction

	Imprisoned		Convicted		Caught	
Probability of Interdiction	Self	Associate	Self	Associate	Self	Associate
0.0*	100%	100%	100%	100%	100%	100%
0.1	20%	53%	31%	65%	39%	77%
0.2	10%	24%	15%	38%	23%	46%
0.4	5%	10%	7%	10%	9%	18%
0.8	3%	7%	3%	4%	6%	15%

* Note that we assume that all respondents would be willing to smuggle at zero risk. This conclusion will be born out by the final model.

Some prisoners voluntarily commented that they *would smuggle* even if they knew beforehand that they would be caught, convicted, or even imprisoned. However, the interview answer categories allowed only a response that they "*would not smuggle*" if they knew they would be caught "every time." Therefore, in our analysis, we assumed that a response to "every time" covered two conditions: those who *would* and those who *would not* smuggle if they knew they were certain to be interdicted. Similarly, inmates were not asked whether they would not be willing to smuggle again even at zero risk.

These ambiguities complicate the interpretation of the response patterns as a mathematical expression, but can be handled by the same techniques applied to grouped data.

C. THE MATHEMATICAL FORM OF THE WILLINGNESS TO SMUGGLE FUNCTION

Figure A-1 is a plot of the cumulative distribution of inmate responses for two of the six cases from Table A-2. It shows the declining fraction of the inmates who remain willing to smuggle against an increasing probability of interdiction when the consequence of being caught is imprisonment. In this section, we will first consider alternative plausible mathematical functional forms for $W(P_I)$ and select the one that best follows the trend of the data. Readers not interested in plausible alternatives may jump to the next section describing the fit of the interview data to the selected function.

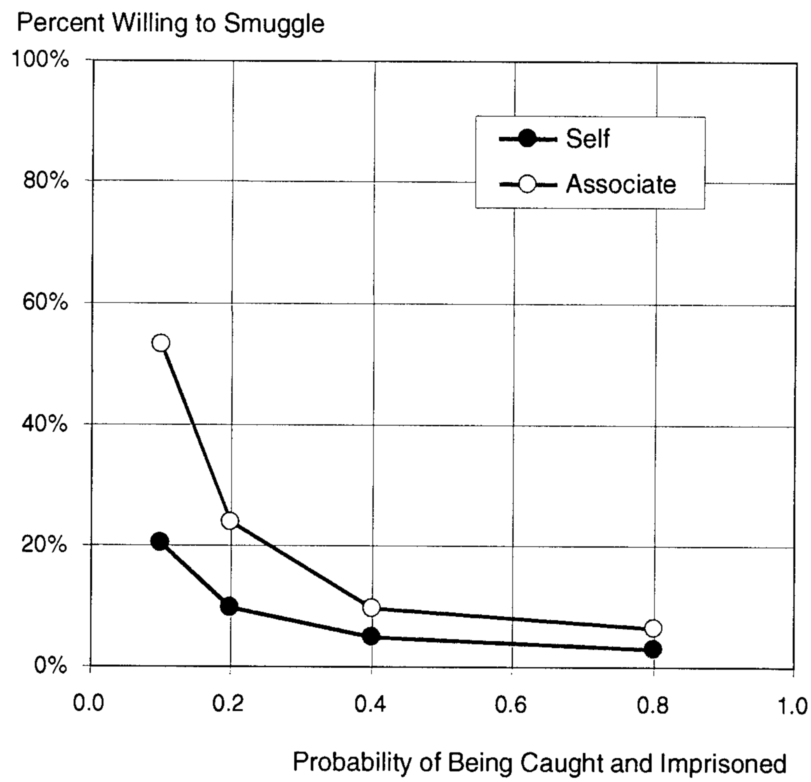


Figure A-1. Cumulative Distribution of the Willingness to Smuggle

1. Three Alternative Mathematical Functions

Constrained by limited data, we considered only the simplest functional forms exhibiting the appropriate qualitative properties. There are three such candidate forms:[1]

$$W(P_I) = (1 - P_I)^{\alpha - 1} \quad \text{Pareto Function (Power Law for } P_d\text{)} \tag{2}$$

$$W(P_I) = e^{-\alpha P_I} \quad \text{Attrition Filter Function (Exponential in } P_I\text{)} \tag{3}$$

$$W(P_I) = \left(\frac{P_I}{P_{\min}}\right)^{-\alpha} \quad \text{Risk Perception Function (Power Law in } P_I\text{) and} \tag{4}$$

$$W(P_I) = 1.0 \quad \text{for } P_I \le P_{\min}$$

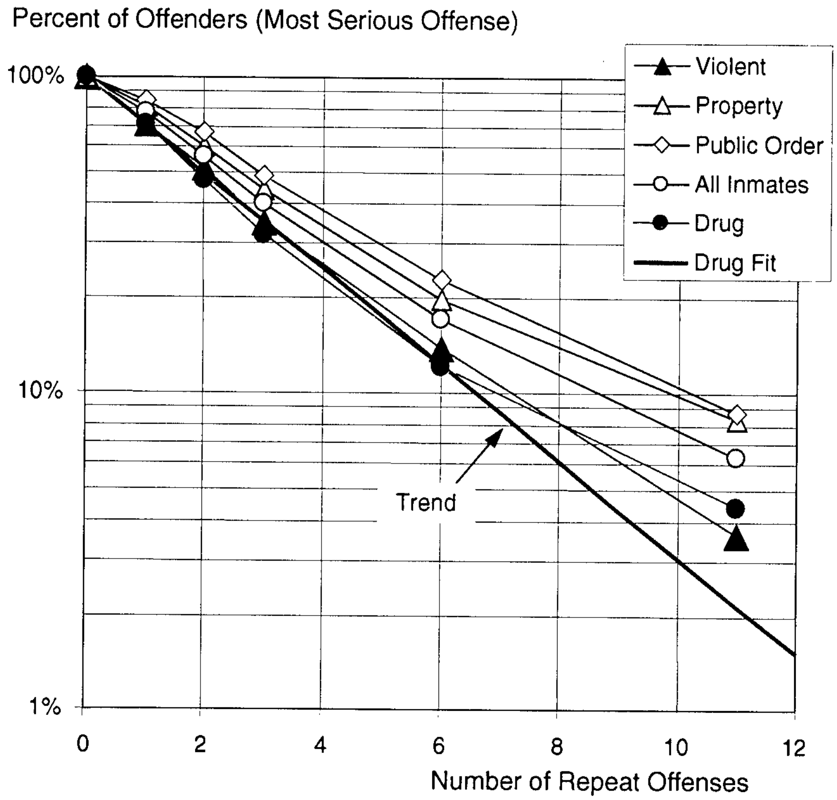
In all of the above, α is a fixed exponent, and for the Risk Perception Function, $P_{\min}$ is another fixed parameter. The Pareto Function matches the general qualitative appearance of military deterrence plots; there are so many examples of this behavior that it is a standard technique of representing data. The Attrition Filter Function represents a multi-stage process of absorption through a series of filters. It is plausible that traffickers experience their activities this way and, therefore, perceive their chances of success in the same way. An example of such a filter process is the willingness of criminals to repeat offenses – the jailhouse revolving door. Figure A-2 shows a cumulative distribution of the percent of offenders who have been put back in jail up to 11 times. For violent or drug related crimes, a crude Attrition Filter Model represents these data rather well. Here, the model's straight-line trend on semi-log plot represents a recidivism rate of 69 percent. Only those with 11 repeats deviate noticeably from the model, yet the model is still within a factor of 2 of predicting this low rate of a few percent.[2]

The Risk Perception Function arises from the psychophysics of perception processes. By the 1950's, S. S. Stevens had shown that people are very accurate judges of ratios of intensities (Ref. 15). For example, human subjects asked to match various light intensities to sound intensities produced a power-law relationship between the two physical intensities. More generally, subjects could be asked to match light intensities to a numerical scale and the power-law relationship still held. Further, matching two scales works well without requiring subjects to adapt a common scale, but rather, letting them select their own numbers and deriving a scale from the *ratios* of the numbers they chose.

---

1 These functional forms are derived in Appendix B.

2 Note that for cumulative distributions, the fitted trend follows the large count right-hand beginning of the data distribution while *systematically* drifting away from the data for lower values based on smaller counts with greater counting fluctuations.



Source: US DOJ Bureau of Justice Statistics: Drugs and Jail Inmates, 1989.

Figure A-2. Percent of Repeat Offenders

One might expect that smugglers would match their perceptions of the penalties of being captured and suffering various consequences against the probabilities of being interdicted in a similar power-law manner. Smugglers would compare ratios of risks with those of consequences in determining their willingness to smuggle.

For each of the candidate functions, Figures A-3 through A-5 plot the interview data for the willingness to smuggle if the consequences of being caught were imprisonment (only two cases are shown for simplicity and to reduce clutter on these plots). In each plot, we chose axes so that the data should fall along straight lines if the underling function were correct.

- The Pareto Function, shown in Figure A-3, consistently curves upward on a log-log plot, violating the hypothesis that the data would form a straight line.
- The Successive Filter Function, shown in Figure A-4, consistently curves outward to the right on a semi-log plot rather than sloping downward in straight lines.

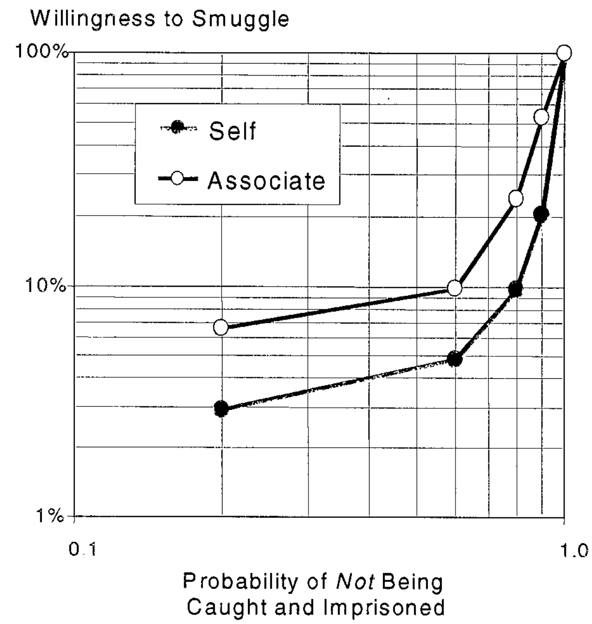


Figure A-3. The Pareto Model

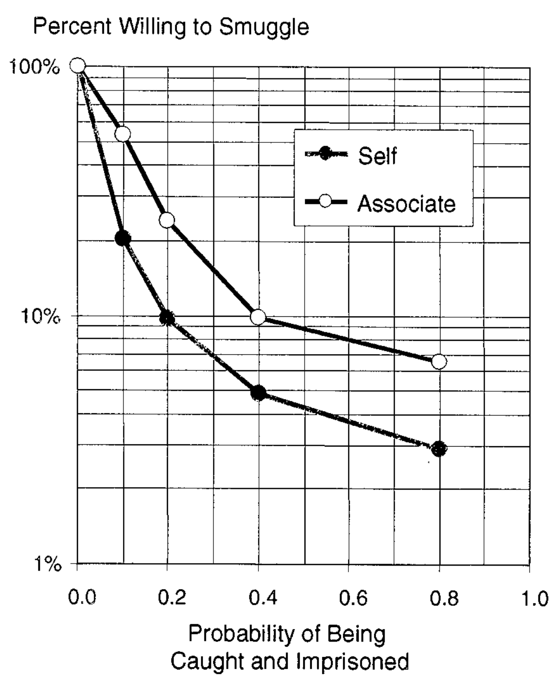


Figure A-4. Successive Filter Model (Exponential Hypothesis)

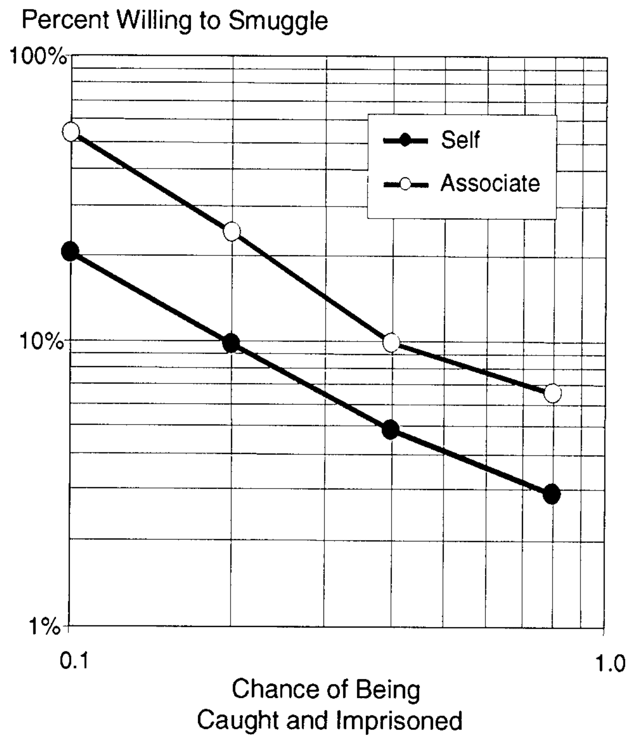


Figure A-5. Risk Perception Model (Power-Law Hypothesis)

- The Risk Perception Function, shown in Figure A-5, approximates straight lines on a log-log plot over the range it can be plotted. Clearly, it is the best of the three approximations.

2. Other Corroboration for the Risk Perception Model

In our literature search, we could only find indirect evidence of functions relating levels of risk to degrees of deterrence for a population participating in a risky activity. In a classic paper, Chauncey Starr inferred the risk trade-offs of the U.S. population at large by examining their willingness to take risks (Ref. 11). His data can be transformed into our representation. Figure A-6 shows the increasing percentage of the U.S. population willing to use automobiles as automobile safety increased. Starr measured safety in fatalities per person-hour of exposure. During the earliest and riskiest period from 1900 to 1910, this trend is also an inverse power relationship with exponent slightly less than –1.0.

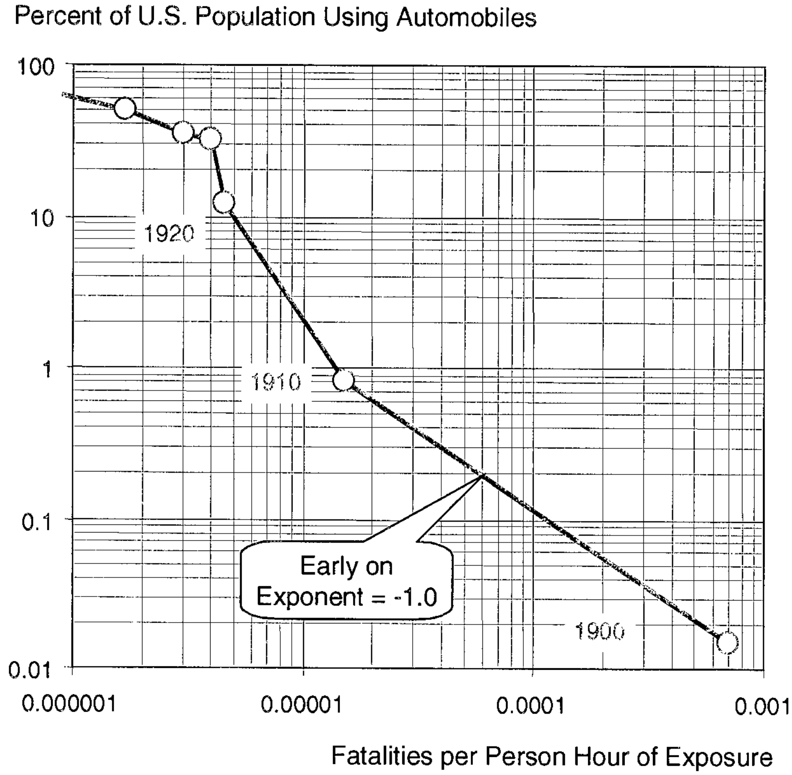


Figure A-6. Percentage of U.S. Population Willing to Risk Using Early Automobiles

Although driving an automobile is a licit activity, at the 0.01 percent level of usage in 1900, it was essentially an "extreme sport." By 1910, at the 0.8 percent level of usage, it had become a somewhat more common recreational curiosity. As automobile usage rose above one percent of the population, it increasingly became a necessity and a social status symbol – usage grew faster than risks declined. By 1960, usage had begun to saturate and safety improved to the degree that the conditions had nearly returned to the original trend line extrapolated from 1900 to 1910. Thus, the early days of automobile use may exhibit a generic pattern of willingness to take risk among the most adventuresome segments of a population.

Starr also showed that people are willing to accept 1,000 times as much risk if they are in control versus someone else controlling the risk. Therefore, it is not surprising to see smuggler pilots in Peru accept more risk from crashes than from interdictors and run from government fighter aircraft knowing they are almost certain to be shot down. We also found several functions and examples that are closely related to our Risk Perception Function in the psychology of risk perception literature. The most widely accepted model of risk perception by individuals is the conjoint expected risk (CER) model (Ref. 13). This model has several parameters and distinguishes the

perceived riskiness of options with positive outcomes from those with negative ones. People tend to be risk-averse when pursuing gain and risk-taking in avoiding losses. The key point for our analysis is the power-law behavior of the model. Both risk aversion and risk taking decision responses to questions vary as power laws of the degree of risk. Alternative psychological models based on comparing gains with expected losses to risks, on expected gains versus the variation of uncertainties, or on exponential rather than power-law representations do not fit the experimental data as well as the CER model (Ref. 13; Ref. 14).

D. FITTING THE DATA TO THE RISK PERCEPTION FUNCTION

We now fit the parameters of the Risk Perception Function to the smuggler interview data. Again, there are several ways to do this because there are six cases to fit – self and associate for caught, caught and convicted, and imprisoned. Appendix B gives the equations and methods used for this fit, while this section summarizes our results including the rationale for our selection of the particular parameters and constraints to fit and the quality of the fit. " question abruptly deviate from this logical order. Clearly, it will be difficult to obtain a universal fit to all cases with this significant deviation. Examination of the data for the "convicted associate" case in Table A-1 reveals that the category 0.2 to 0.4 has about six too many responses while the category 0.8 to 1.0 has about six too few to be consistent with the progression of values established by the other two "associates" cases. Although six responses are outside the range of statistical uncertainty, it is a small bias relative to an interview process involving 109 respondents. For this reason, we assume that these few responses were flawed and distorted; therefore, we dropped this case from our overall statistical fit determining the exponent.

1. Fitting the Risk Perception Function to Inmate Interview Data

Figure A-7 shows all three of the cumulative trends for both self and associate. Note that the data points at "probability of being caught or imprisoned" equal to 0.1 follow a regular progression in "percent willing to smuggle" for all six cases. The progression from the top down is associate-caught, associate-convicted, associate-imprisoned, self-caught, self-convicted, and self-imprisoned. This progression makes sense because the inmates are more willing to smuggle against less severe penalties and because imprisoned smugglers judge the consequences more severely than they imagine their former associates would have while free.

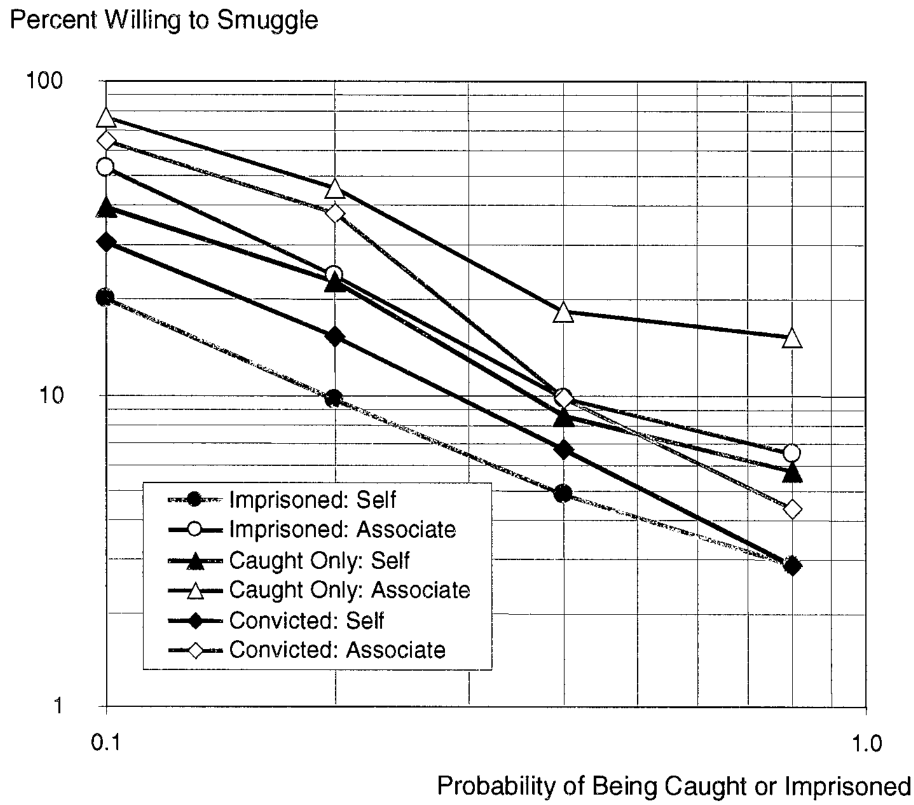


Figure A-7. Risk Perception Model with All Data Shown

At a probability of 0.4 and on to 0.8, however, responses to the "convicted associate" Clearly, it will be difficult to obtain a universal fit to all cases with this significant deviation. Examination of the data for the "convicted associate" case in Table A-1 reveals that the category "2 in 5" has about six too many responses while the category "every time" has about six too few to be consistent with the progression of values established by the other two "associates" cases. Although six responses are outside the range of statistical uncertainty, it is a small bias relative to an interview process involving 109 respondents. For this reason, we assume that these few responses were flawed and distorted; therefore, we dropped this case from our overall statistical fits determining the exponent.

Appendix B describes our statistical fitting process in more detail, but we highlight its main features here. First, we treat the grouped data by taking differences of the *cumulative* distribution at upper and lower values of probability of interdiction for each bin. This estimates the number of inmates who would respond in a given bin for a given pair of hypothesized parameters – exponent and P_{min}. The last two bins, 0.4 to 0.8

and 0.8 to 1.0, were combined because to be accurate the least square fitting and the chi square estimate of quality of fit require more than four counts per bin.

We began by assuming a power-law exponent of –1.0, but this produced normalized residuals that were systematically negative for all but the first risk probability category for most of the cases. Next we went to the opposite extreme and fit each of the cases with a different exponent. As expected, the "convicted associate" case was the only one to have a totally unacceptable chi square probability; it was 0.001. However, the large correlation between the two parameters ranging from 0.56 to 0.93 caused large uncertainties estimates for both parameters, especially the exponent. Because the six exponents were consist with having the same value, we finally chose to fit the five reliable cases with a common exponent and force the "convicted associate" case to use that exponent while fitting its $P_{\min}$.

The fit with a common exponent yields a value of –1.029 and an uncertainty of ±0.068, which of course spans –1.0. The $P_{\min}$ values and their respective standard deviations are shown in Table A-3.

Table A-3. Risk Perception Function Parameters for the Fit with Common Exponent

Parameter	Self			Associate		
	Imprison	Convict	Catch	Imprison	Convict	Catch
$P_{\min}$	0.021	0.032	0.041	0.054	0.068	0.078
Standard Error	0.004	0.005	0.005	0.005	0.004	0.004
Common Exponent	1.029					
Standard Error	0.068					

Table A-4 gives the chi square and its probability for the above fit. The chi square measure of quality of fit would be close to 0.5 for purely random fluctuations about a typical representation. Our fit to the risk perception function without the convicted associate case gave a very plausible probability of 0.49, while with the deviant case, "convicted associate," there would have been a very low probability of 0.022.

Table A-4. Overall Chi Squares and Probabilities

	All Series	All Series but Convicted Associate
Chi Square	19.40	8.43
Probability	0.022	0.491

Considering that these data were obtained from interviews and combine responses from smugglers of all types of drugs, Table A-5 shows a remarkable agreement between the data and fitted values for our simple risk perception function. Although we combined the last two bins for the fit because they often had values less than 4, Table A-5 shows the data and functional estimates separately.

Table A-5. Comparison of the Fitted Values to the Inmate Responses for All Six Cases

Case		Probability of Interdiction Range				
		0.0 to 0.1	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8	0.8 to 1.0*
Imprisoned Self	Data	83	11	5	2	3
	Fit	83.0	10.7	5.2	2.6	2.5
Convicted Self	Data	72	16	9	4	3
	Fit	71.9	16.3	8.0	3.9	3.8
Caught Self	Data	63	17	15	3	6
	Fit	62.1	21.4	10.5	5.1	4.9
Imprisoned Associate	Data	43	27	13	3	6
	Fit	42.8	25.1	12.3	6.0	5.8
Convicted Associate	Data	32	25	26	5	4
	Fit	30.0	31.6	15.5	7.6	7.3
Caught Associate	Data	21	29	25	3	14
	Fit	20.5	36.5	17.9	8.8	8.4

* This bin includes those who would smuggle knowing they would be interdicted.

Because the exponent is essentially –1.0 and the function is simple, there may be a universal risk perception relationship underlying these results. This would explain why smugglers involved with very different drugs and quantities of drugs could follow a common function. A universal relationship might also explain why participation in the early high-risk and sporting days of automobile use followed a power law with –1.0 exponent of risk. It might also explain why violations of fisheries laws and restrictions fall off as the inverse of the probability of being inspected (Ref. 12).

2. Threshold of Deterrence

We interpret the risk perception function to imply that the smugglers entirely ignore some small probability, P_{min}, of being interdicted. This small probability is a *threshold* degree of interdiction risk that must be exceeded before any of them are deterred. Once this threshold has been exceeded, however, interdiction probabilities only

somewhat larger deter relatively large numbers of would-be smugglers. This threshold is a breakpoint at which deterrence sets in – a strongly non-linear feature of the function and of deterrence in general.

The risk perception function also implies that a *non-zero* fraction of the smuggler population would be willing to smuggle even if they knew they would fail – a fraction that is *never deterred.* Mathematically, this result is a consequence of setting $P_I = 1.0$, that is, evaluating the risk perception function assuming the smuggler is certain to be interdicted.

$$W(P_I) = \left(\frac{1.0}{P_{\min}} \right)^{-1.029} = P_{\min}^{1.029} > 0.0$$

Inmates volunteered comments that validated this surprising result. Some said that the bonuses they received provided for their families better than the wages they could have earned during the time they were in prison. Note that because $P_{\min} \leq 1.0$, raising it to a power slightly greater than 1.0 yields a result slightly less than $P_{\min}$ itself. Finally, we can overlay the fitted trend lines on Figure A-7 to obtain Figure A-8.

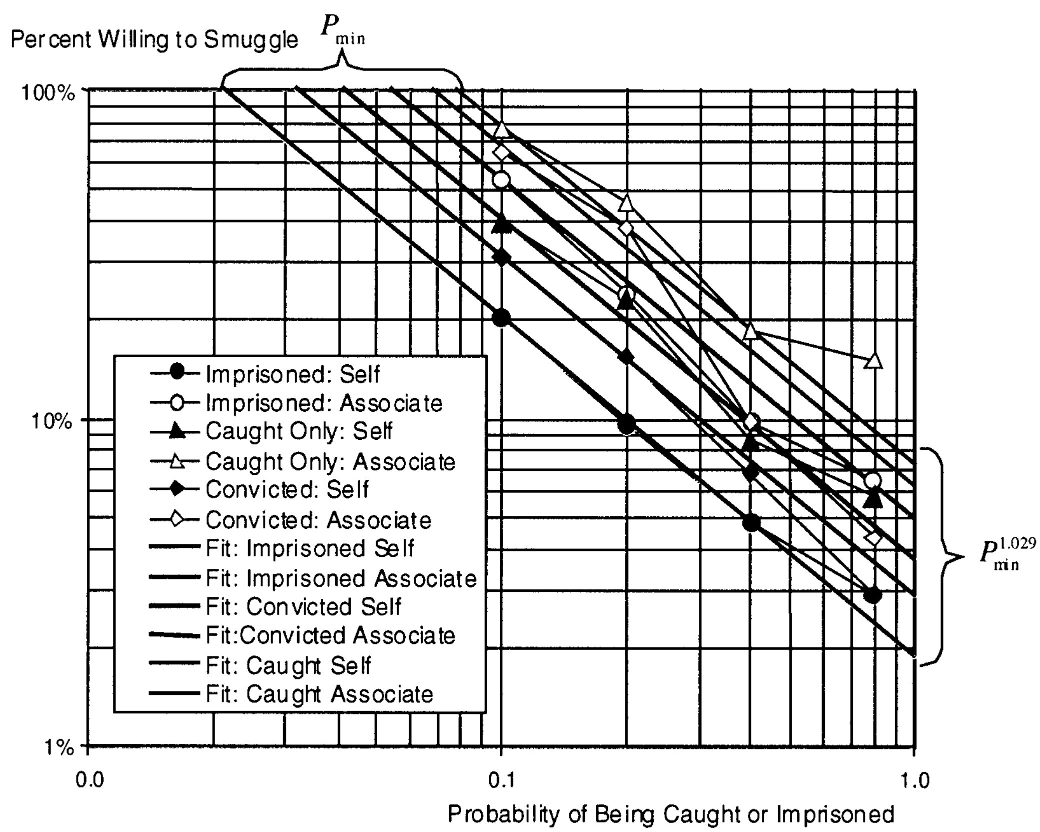


Figure A-8. Risk Perception Function Trend Lines Overlaid on Cumulative Data

Without the log-log transformation, one can see the thresholds and residual never deterred fractions much better. Figure A-9 shows the four extreme cases from the interviews superimposed on lines paralleling the fitted trends. We chose the lines to separate operational "deterrence zones," which will be explained in more detail later. The three lines separating the deterrence zones have P_{min} threshold values of 2.0, 5.0, and 13 percent respectively.

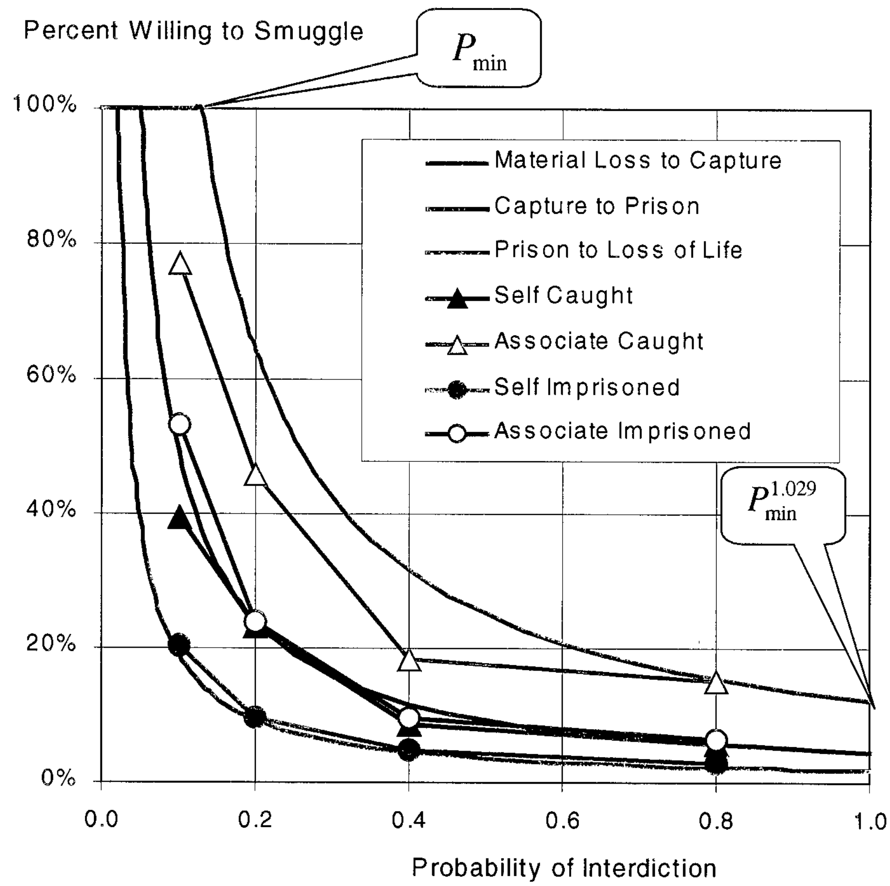


Figure A-9. Willingness to Smuggle Data and Deterrence Zones

E. PROBABILITY OF DETERRENCE

Given the mathematical form of the risk perception function, equation (3), we can again address the probability of being thwarted P_t in equation (1):

$$P_t = 1 - (1 - P_I) \cdot \left(\frac{P_I}{P_{\min}} \right)^{-1.029} \quad (1)$$

where $P_{\min}$ depends upon the consequences of being caught. This equation applies only for $P_I \geq P_{\min}$ because up to $P_{\min}$ there is no deterrence, only interdiction. Figure A-10 plots the final deterrence model for several values of $P_{\min}$. Each value defines a contour that divides different deterrence "zones." Deterrence zones represent distinctly different consequences according to the perceptions of smugglers. These are as follows:

- Lethal Force (2 percent or less): much below 0.7 percent, smugglers generally ignore interdiction risks even if the consequences can be fatal. Between 0.7 to 2 percent, risks become too great to ignore and some are deterred by lethal risks. Figure A-10 shows lines at 1.16 and 2.0 percent.

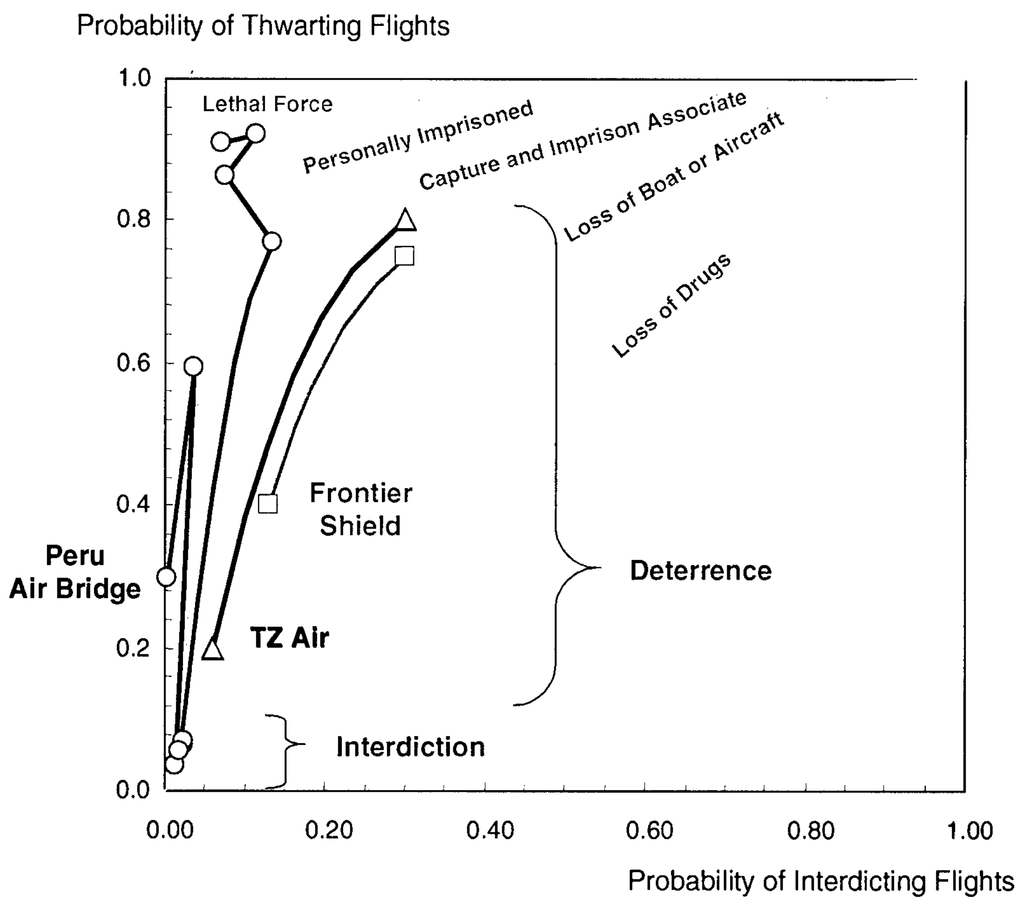


Figure A-10. Deterrence Model Overlaid with Data from Three Operations

- Personally Imprisoned (2 to 5 percent): traffickers, who have experienced imprisonment, begin to be deterred by the risk of more imprisonment.

- Capture and Imprisonment of an Associate (5 to 13 percent): those who have not experienced prison life are likely to continue until the risks are higher before they start to be deterred.
- Loss of Boat or Aircraft (13 to 30 percent): those who lose their boat or aircraft most often lose their drugs as well.
- Loss of Drugs (over 30 percent): we will present additional findings from the interviews suggesting that traffickers are willing to lose 30 percent of their loads on average before they are deterred.[3]

Figure A-10 shows two Caribbean transit-zone operations, one against direct air flights and another, Frontier Shield, against traffic along Eastern Caribbean routes and Puerto Rico (Ref. 16). During these operations traffickers were at risk of capture and imprisonment but not lethal action. The air traffic was deterred almost entirely and traffickers soon learned to avoid the routes to the Eastern Caribbean. Note that these operations fall within the "imprisonment of associate" zone.

Figure A-10 also shows the complex pattern of responses to operations against the air bridge carrying coca base from Peru to Colombia. Although not sanctioned by the U.S. Government (USG), Peruvian fighters "accidentally" fired upon traffickers during Support Justice III (SJ III), and the operation ended when they shot into a USG C-130 airplane over Peru. Tighter limits on the use of lethal force resulted in traffickers largely ignoring the low rate of interdiction achieved during SJ IV. After a Presidential finding authorizing USG support to interdictions that might end with lethal force, the Peruvian Air Force (FAP) with U.S. radar and intelligence support was able to interdict enough trafficker flights to deter most from continuing to smuggle. The sustained level of interdictions per month further increased the interdiction rate to greater than 13 percent. Unwilling to sustain these losses, trafficker flights and losses fell back into the expected "lethal" zone of values by 1996. At this time, over 80 percent of the traffickers were deterred.

F. OTHER ASPECTS OF DETERRENCE

Several other inmate responses provide useful information about the deterrence of smuggling operations that could improve interdiction efforts.

---

3 We will explain that the inmates were asked to answer as if they were the non-smuggler trafficker/owner of the drugs. These responses did not follow a clear pattern. They fit an exponential better than a power law of the deterrence model. For the exponential, the average was about 30 percent, but if forced to follow the "best fit" power law, the thresholds were approximately 7 to 9 percent.

1. Willingness to Change Location of Smuggling

Inmates were asked whether various probabilities of interdiction would cause them to change their smuggling location if the consequence was simply being caught. Figure A-11 shows their responses plotted in the by-now-familiar log-log format of our function representing the willingness to smuggle. We also show two zone boundaries, 2 and 5 percent, that trace the onset of deterrence with a consequence of imprisonment for self and associate, respectively. The willingness to change location clearly parallels that for deterrence in general, but the threshold for "self" changing location is 95 percent higher than the threshold to be deterred and 44 percent higher for "associate."

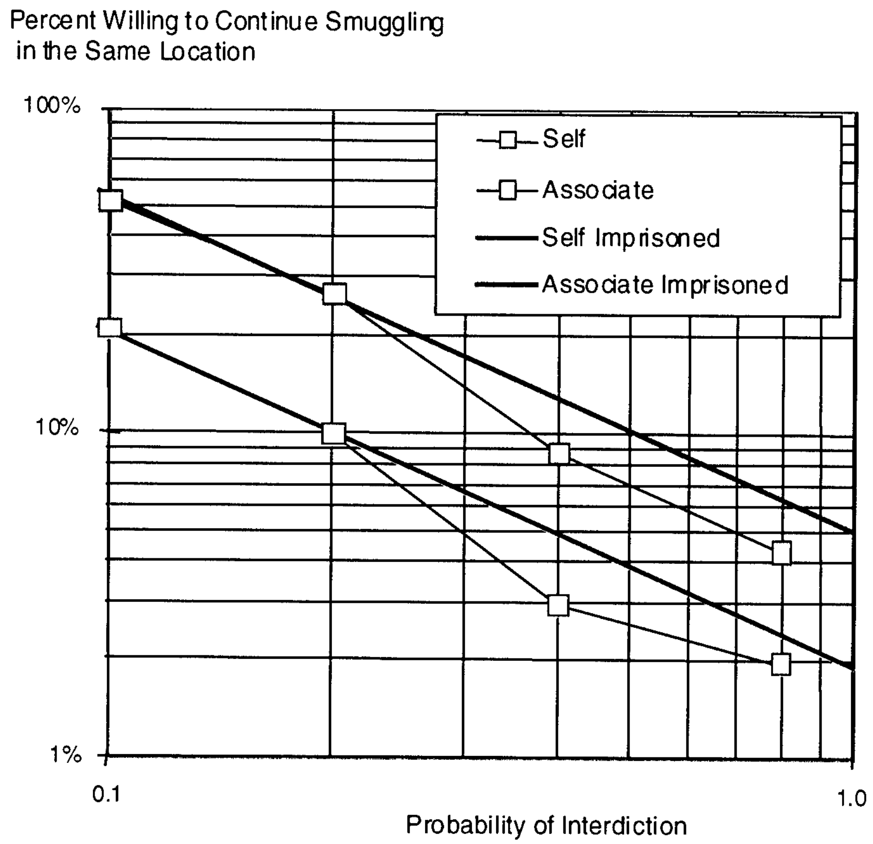


Figure A-11. Willingness to Continue Smuggling at the Same Location

2. Perceived Chance of Being Caught

On average, inmates estimated their chance of being caught as 0.30, or once in every 3.33 attempts. This rate of 0.3 for "self" is unrealistically high and may reflect

their chagrin at being imprisoned.[4] They also estimated the chance of their "associate" being caught as 0.134, or once in every 7.4 attempts. This is very close to the 6 times the average inmate said he had previously smuggled.

3. Willingness to Lose Loads before Stopping or Changing Methods

Inmates were asked how many loads a smuggler, or a source who did not smuggle, would be willing to lose before stopping or changing methods. They could respond with choices from 1 to 10 loads. Figure A-12 shows that these distributions are approximately *exponential*, that is, straight on a semi-log rather than log-log plot. This is unlike the risk perception function, which was a power law. Since the interviews were capable of generating two very different classes of functions, the power law in the risk perception model is not simply an unavoidable artifact of the interview process.

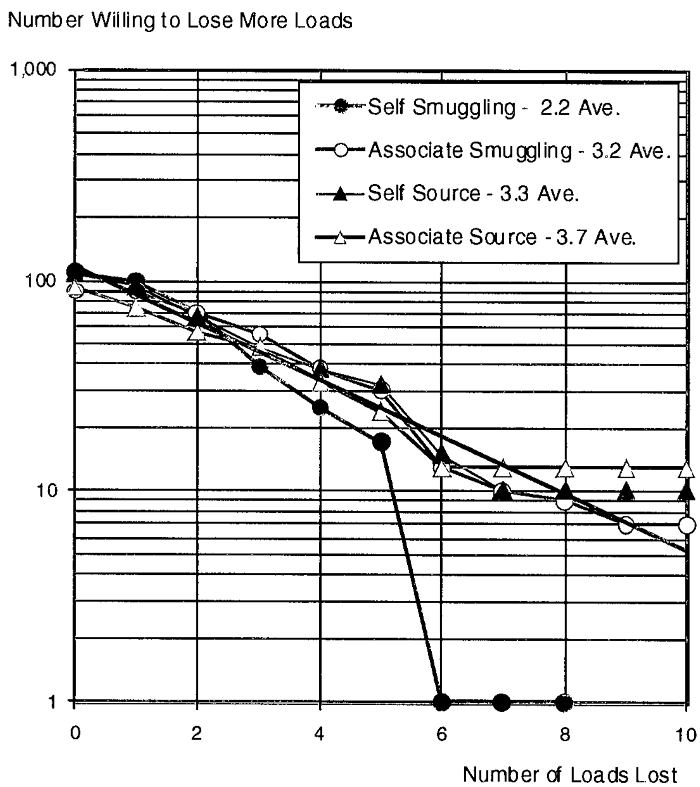


Figure A-12. Willingness to Continue after Losing Loads

---

4 The 0.134 is about 1.7 times the largest deterrence threshold, 0.078, for an associate's willingness to smuggle if the consequences were only being caught, a minor inconsistency among these interview responses. Later we infer from rendering the willingness to take more risk for more wage with the original deterrence cases that inmates respond as if they perceived the current risk to be 5 percent. This value is the same for both self and associate responses.

As seen for criminal recidivism shown in Figure A-2, an exponential distribution is expected from the filtering effect of multiple sequential losses. Here again, a series of risk filters, sequential chances of losing loads, compounds with more attempts. Apparently, respondents perceived risk of failing as remaining the same each time as the last. Because the distribution is exponential, the mean value is a good estimator of overall willingness to lose loads. The mean values are shown in Table A-5 along with one trend line for "self" as the source. Note that the cumulative distribution in these plots can and does wander far from the best-fit trend line, especially for self smuggling.

Table A-5. Anticipated Number of Drug Loads Lost before Deciding to Stop or Change Methods

Decision Made by:	Actor	Mean Number of Loads
A Smuggler	Self	2.2
	Associate	3.2
An Owner of Drugs and Non-Smuggler	Self	3.3
	Associate	3.7

4. Willingness of Owners to Lose Loads Before Stopping

The inmates were also asked what loss rate would be necessary to stop owners of drugs from sending loads assuming they did not do the smuggling. Again, this is a filtering question, and the distribution is exponential.[5] If the inmates were the owners of the drugs, they would have to lose 31 percent of their loads.[6] This is the basis for the

---

5 These data fit an exponential better than a power law; however, neither fit is consistent in all cases. Chi square probabilities for the exponential hypotheses are 0.69 for self and 0.0013 for associate. A forced fit to the power-law willingness function give much worse chi square probabilities of 0.025 for self and 0.000,000,1 for associate.

6 The 31 percent is a weighted average of the raw data for self as owner, and 43 percent is for associate as owner. Better average estimates are obtained by fitting the data to an exponential, an ideal filter model. This yields a 22 percent average for self and a 35 percent average for associate. These are still in the range of the 30 percent "threshold"

An area for future research is tying the deterrence of owners into the overall deterrence model. By force-fitting the inmate responses to an inverse power law, we obtain the following thresholds, but with very poor chi squares as mentioned in previous footnote. The P_{min} are 6.6 percent for self and 8.6 percent for associate. These thresholds change little if the exponent is fit along with the P_{min}; the chi squares also do not improve.

Although thresholds in the 7 to 9 percent range for loss of drugs would change the deterrence model for the larger thresholds, it would not change the estimated thresholds used to plan operations against the more easily deterred smugglers. Operational experience in Peru and the Caribbean provide calibration for these operational regions of the deterrence model. Whether trafficker/owners are

zone boundary for lost drugs at $P_{min} = 30$ percent. If the inmates' associates were the owners, they would have to lose 43 percent of their loads. If these values are representative, it is nearly impossible to deter smuggling through seizures alone because it is unlikely these percentages could be achieved in practice.

5. Other Important Smuggler Comments

Smugglers volunteered important information during the interviews. Some of this is relevant even 10 years after those interviews.

- Smugglers prepared carefully before an attempt.
- When the Government launches a major operation, it is well publicized and generally not sustained. Thus, smugglers believed they could go around the operation or wait it out.
- One smuggler said that if the severity of typical sentences were known, most smugglers he knew would resist arrest with force.
- For marijuana smugglers, there is a stigma associated with cocaine smuggling.[7]
- Some smugglers were *attracted* by the thrill, and also said they had not previously understood the harm the drugs caused. This provides qualitative validation to the risk perception function with a P_{min} threshold before deterrence begins.
- Most smuggling organizations consist of about 10 people – two who set up purchases, two or more who smuggle depending on the mode of transportation, and four to six involved in unloading and distribution at the receiving end. These small organizations were independent from large "organized crime" trafficker groups.
- Major smugglers, carrying hundreds of kilograms of cocaine or tons of marijuana, were well educated. Two in the sample had Ph.D.'s.

G. ABILITY OF WAGES TO COMPENSATE RISK

During the Rockwell interviews, the drug smugglers were asked whether higher fees or "wages" would compensate for higher risks. To some extent wages would, but a closer examination of the trends show that this is an impractical way to offset the risks.

---

deterred at 9 percent or 30 percent, they are still much more willing to lose loads than smugglers are to lose their freedom or their lives.

7 This underscores the potential bias resulting from combining both sets of data. However, the internal consistency of the model and its agreement with available data enhance its credibility.

The literature on risk perception, and specifically the value of money in risk situations, explains why it is impractical to offset risks by higher monetary returns.

a. Some Background on Money and Risk

Gabriel Cramer first conjectured in 1728 a decreasing "utility" of money in the context of risk taking (Ref. 15). He conjectured that gamblers perceived the subjective value of money to be proportional to only the square root of its face value. This is equivalent to saying gambler's monetary losses must increase with an exponent of 2.0 to significantly inhibit their willingness to take the gamble.

S. S. Stevens reported experiments in France, the U.S., and Canada in which subjects assigned numerical values to the relative seriousness of crimes (Ref. 15). The list of crimes ranged from thefts without threat of harm up through physical assaults. The relative seriousness of the crimes were consistent among all the experimental groups, and the theft amounts embedded in the list of crimes formed a ratio scale. Figure A-13 shows that the perceived seriousness of the thefts *strongly* discounts the face value of the money. Seriousness of a theft goes up only as the 0.22 power of the face value. Thus, the dollar amounts of thefts must increase as an indicator of perceived seriousness of the crime raised to the 1/0.22 = 4.5 power. These examples show that the perceived value of money is greatly discounted against gambling risk or perceived seriousness of crimes and, further, that the perceived discounting follows power-law functions.

b. The Interview Data

To some extent, as the wage offers increased, more smugglers said they were willing to take the risks. Different questions addressed increased risk levels of x2, x3, and x4, the current risk, and a last question explored certain capture. For each level of The interdiction penalty associated with all risk levels was being caught and convicted. risk, additional compensation of x2, x3, x4, x5, and x10 were offered to offset the risks. These cumulative distributions are shown in Figure A-14 for each risk level and for both "self" and "associate." As always, the associate was perceived as taking more risk for the same compensation. At double the risk, most everyone who was willing to smuggle would do so at only double the wages. We indicate this for associates in Figure A-14 by a red open circle at 40 percent and x2 risk. For x3 the risk, however, compensation increases the number willing up to about x5 the current compensation – thereafter, there is little increase with compensation. For x4 the risk, the number of takers is still

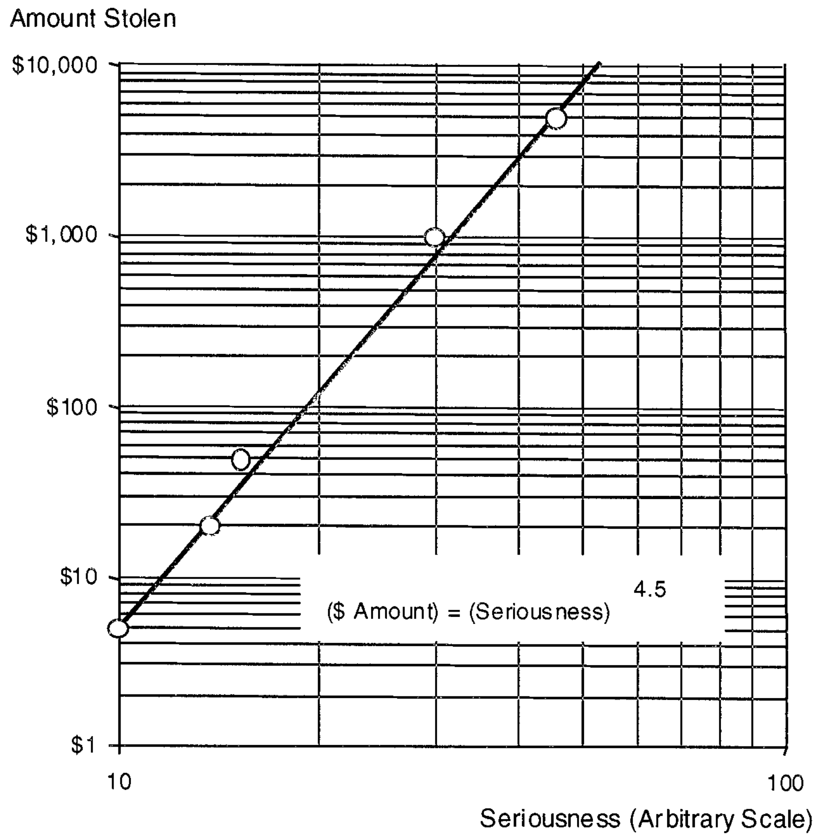


Figure A-13. Perceived Seriousness of Thefts versus the Face Value Stolen

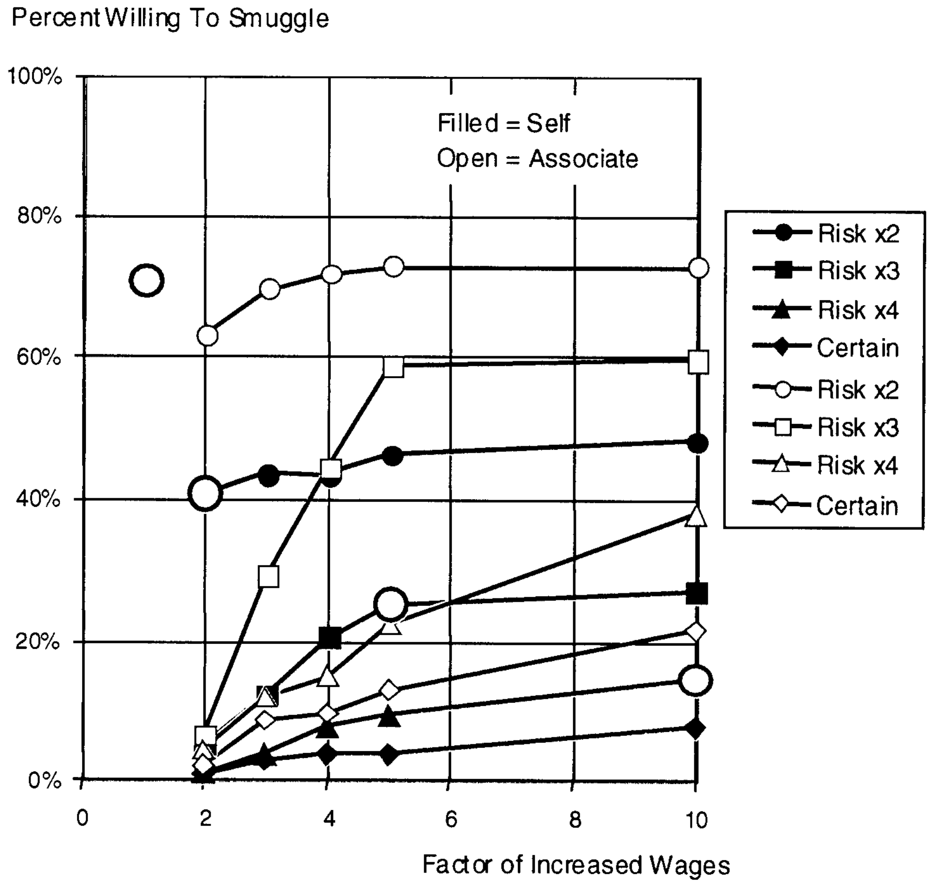


Figure A-14. Increase in Willingness to Take Risks with Increased Wages

increasing at x10 the wages. Therefore, the interview data show that increased wages can induce a few more to smuggle, but the wage offers are increasing more rapidly than the risks.

Speaking for themselves, only 15 percent of the smugglers were willing to continue even at x10 the compensation. Speaking for their imagined associate, capture would have to be certain to drop their willingness to 22 percent. Although a few more are willing to smuggle for higher wages, those willing represent a rapidly decreasing portion of the total population of smugglers.

c. The Impracticality of Offsetting Risks with Wages

Now we can apply the findings from gamblers and perceived seriousness of crimes to the perceptions of smugglers revealed by the interviews. We examine the rate of increase in wages necessary to induce smugglers to accept factor increases in risk. From Figure A-14, we can estimate the factor of increase in wages that attracts nearly all

those who are willing to smuggler at a given level of risk. The red open circles trace the implied relationship between factor increases in wages versus factor increases in risks. Note that there is not much difference between x4 risk and certain capture for "self."

Figure A-15 plots the relationship between factors of risk and factors of wage implied by the red circles. As one might expect by analogy with gamblers who discount the face value of money in risk taking to the degree that wages must rise in proportion to the *square* of the increased risk, the excellent quadratic fit to smuggler behavior represents an identical discounting. Most smugglers choose to face risks to pursue a reward as opposed to avoiding a loss.[8] Bell, Raiffa, and Tversky (Ref. 103) discovered there is an asymmetry for accepting a risk to pursue a reward versus avoid a loss, and later Weber and Luce (Ref. 14) included this distinction in their model. Essentially, people are much more willing to accept risks to avoid losses than to pursue gain. Although smugglers are risk seekers as a class, they are individually risk averse relative to the value of money rewards in agreement with the above well-tested theories. Whether or not these theories apply, it is clear from interview data and from steeply rising smuggler fees over the Peruvian air bridge that increasing wages will not entice current smugglers to face any significant increase of interdiction risk and is an ultimately losing strategy for traffickers.

d. Expectation of Increased Wages at Higher Risks

We asked ourselves whether the inmates answered the willingness-to-smuggle questions with the expectation of increased wages when they indicated they would be willing to continue against higher risks of interdiction. If we accept their responses to the questions about more wage for greater risk as representative, then the following consistency argument implies that the inmates did in fact expect more compensation for greater risk when the answered the willingness questions.

---

8 Some smugglers may be avoiding risks, for example, those desperate for money to avoid some other great loss, those being extorted into smuggling by threats against family members, and those psychologically bent toward self-destruction.

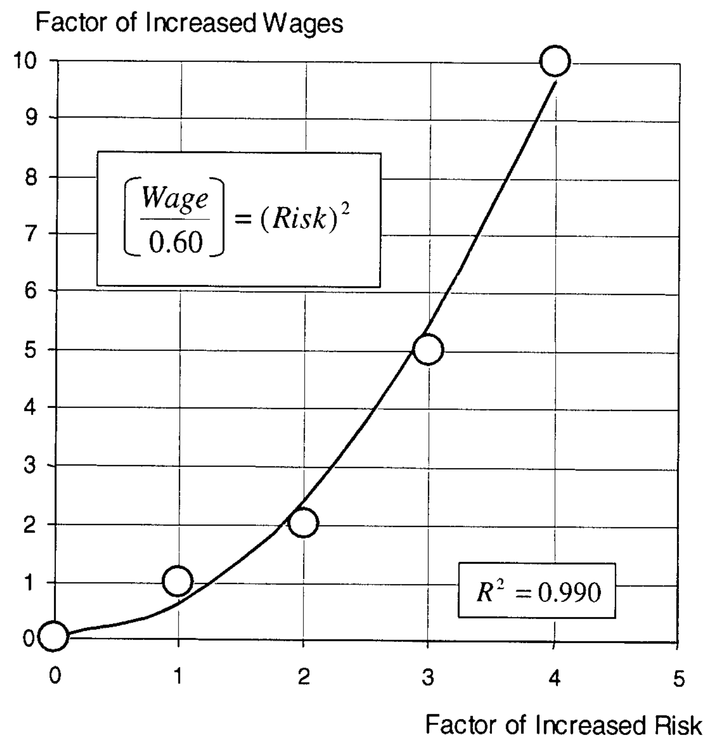


Figure A-15. Quadratic Increase of Wages with Risk

Consider the inmates' responses to the offer of x2 wages to smuggle against x3 risk. Answering as "self," only 4.7 percent were willing. If we compare this to the willingness to smuggle responses for the equivalent consequences of caught and convicted, the probability of interdiction would have to have been 62 percent to only have 4.7 percent willing. This would imply that the current risk was perceived to be 62/3 = 21 percent. If most smugglers believed the interdiction rate were that high, they would not be smuggling now according to the interview results. The corresponding result for inmates answering for their "associate" yields 6.5 percent willing, a 97 percent interdiction rate at x3 risk, and a current risk of 32 percent – equally implausible.

Now suppose that most inmates answered the willingness question under the assumption that compensation offers would increase with risks. At x4 the compensation, most who would smuggle against x3 risk said they would continue. Under these conditions, 20.7 percent answering as "self" would be willing, which corresponds to an interdiction rate of 14.7 percent on the willingness function. One-third of this is 4.9 percent, a reasonable estimate of their current perceived likelihood of being caught. For "associate," 44.6 are willing at x4 the wage, the interdiction rate for this willingness is

14.9 percent, and the current perceived likelihood of interdiction would be 5.0 percent, which is consistent with "self."

As a check, we compared these results with those for x2 risk and x2 wages. For "self," 40.2 percent would smuggle, which corresponds to a 7.7 percent interdiction rate and a current perceived risk of 3.8 percent. Within the statistical uncertainties of the estimates obtained from x3 risk. Finally, "associate" willingness was 63 percent corresponding to an interdiction probability of 10.7 percent and a current perceived risk half this at 5.4 percent – again consistent with the above result.

Repeating the analysis for x4 risk shows that x5 wages yield estimates of current risk as 8.2 percent for "self" and 7.2 percent for "associate." With x10 wages these values drop to 5.0 and 4.3 percent respectively, consistent with the above cases.

Overall, we conclude that the inmates implicitly assumed they would be offered higher wages for taking more risk as they answered the questions about their willingness to smuggle. Furthermore, the two sets of data imply that the inmates, in these 1989 interviews, answered as if they perceived their chances of being interdicted to be between 4 and 5 percent.

APPENDIX B

MATHEMATICS OF FITTING THE DETERRENCE MODEL

APPENDIX B
MATHEMATICS OF FITTING THE DETERRENCE MODEL

This Appendix explains the mathematical formulation of the alternative deterrence functions described in Appendix A and the methods used to fit the parameters of risk perception function to the grouped interview data. Because grouped data preclude the use of standard statistical packages, we devised methods that could be implemented on Excel™ spreadsheets and readily provide bounds on the uncertainties involved in statistical fitting.

A. ALTERNATIVE FORMS OF A DETERRENCE MODEL

There are several general mathematical forms that could represent the qualitative features of deterrence models. We formulated these alternatives in terms of a "willingness to smuggle" function, $W(P_I)$, where P_I is the probability of interdiction. Appendix A compared these alternative willingness functions to the inmate interview data sets to determine that the risk perception model was the most promising candidate.

If we write for any deterrence model, the probability of being thwarted, that is interdicted or deterred, as P_t, Appendix A explains that this can be expressed in terms of an unknown willingness function as follows:

$$P_t = 1 - (1 - P_I) \cdot W(P_I) \qquad (1)$$

We next examine three specific formulations for $W(P_I)$, each parameterized in terms of some constant nonnegative constant α that can be determined empirically from the available data.

1. Pareto Model

The Pareto Model form of P_t is the following:

$$P_t = 1 - (1 - P_I)^{\alpha}$$

where $\alpha \geq 1.0$. Equating this form with that of (1) above yields the form given in Appendix A:

$$W(P_I) = (1 - P_I)^{\alpha - 1}$$

2. Exponential Model

The exponential model has an exponential decay of willingness with increased interdiction risk to that:

$$P_t = 1 - (1 - P_I) \cdot e^{-\alpha P_I},$$

so $W(P_I) = e^{-\alpha P_I}$ for all $\alpha \geq 0$.

3. Risk Perception Model

The risk perception model has an inverse power decay of willingness, which introduces a non-linearity near the origin of P_I at $P_{\min}$. For $P_I \geq P_{\min}$, we have:

$$P_t = 1 - (1 - P_I) \cdot \left(\frac{P_I}{P_{\min}} \right)^{-\alpha}$$

so for the risk perception function $W(P_I)$ is in general:

$$W(P_I) = \left(\frac{P_I}{P_{\min}} \right)^{-\alpha} \quad \text{whenever } P_I \geq P_{\min}$$

$$= 1.0 \qquad \text{whenever } P_I \leq P_{\min}.$$

B. CHI-SQUARE FOR GROUPED DATA

The interview data are called "grouped" data because inmate responses were aggregated into intervals containing all responses greater than a lower limit but less than an upper limit of probability of interdiction. This means that we do not have data with a point density function; rather, we have sums over the point density function from a lower to an upper limit for each group of data. Thus, the willingness function, $W(P_I)$, is a cumulative distribution – representing all responses up to and including P_I. The differences of this cumulative distribution, that is, $W(P_I)$ evaluated at a smaller $P_{I,i}$ minus $W(P_I)$ evaluated at a larger $P_{I,i+1}$, represents the fraction of respondents willing to smuggle if the probability of interdiction were $P_{I,i} \leq P_I \leq P_{I,i+1}$.

We now formulate the chi-square, X^2, for this model and show how we obtained the best fit defined by the minimum chi-square.

1. General Formulation

The expected number of responses, $\bar{n}_i(\alpha)$, in a given group defined by $P_{I,i} \leq P_I \leq P_{I,i+1}$, with a parameter, α, would be:

$$\bar{n}_i(\alpha) = N \cdot (W(P_{I,i},\alpha) - W(P_{I,i+1},\alpha)) .$$

The expression for X^2 would then be:

$$X^2 = \sum_i \frac{(n_i - \bar{n}_i)^2}{\bar{n}_i}$$

where n_i is the number of responses in the i^{th} grouped bin and the sum is over all bins. This expression is subject the constraint that the sums over the n_i and the $\bar{n}_i(\alpha)$ equal *N*, the total number of responses in the data set.

To apply the X^2 as a measure of the quality of the fit or its minimum as a criterion for the best fit, we must meet the condition that each $\bar{n}_i(\alpha)$ is large enough to apply the central limit theorem approximation on the variation from counting statistical fluctuation about $\bar{n}_i(\alpha)$. This condition is met well enough for our purposes if the $\bar{n}_i(\alpha) \geq 4$ for all *i*.

2. Grouped Data for Risk Perception Model

The non-linearity of the risk perception model at $P_I = P_{\min}$ and the ambiguity of the responses for the last bin complicate the formulation of the $\bar{n}_i(\alpha)$ for this model. There are only four bins for each case, and we defined the $\bar{n}_i(\alpha)$ for each as follows:

$$0.0 \leq P_I \leq 0.1 \qquad \bar{n}_i(\alpha) = N \cdot (1 - \left(\frac{0.1}{P_{\min}}\right)^{-\alpha})$$

$$0.1 \leq P_I \leq 0.2 \qquad \bar{n}_i(\alpha) = N \cdot P_{\min}^{\alpha} \cdot (0.1^{-\alpha} - 0.2^{-\alpha})$$

$$0.2 \leq P_I \leq 0.4 \qquad \bar{n}_i(\alpha) = N \cdot P_{\min}^{\alpha} \cdot (0.2^{-\alpha} - 0.4^{-\alpha})$$

$$0.4 \leq P_I \leq \infty \qquad \bar{n}_i(\alpha) = N \cdot P_{\min}^{\alpha} \cdot 0.4^{-\alpha}$$

where we must verify that in the first bin $P_{\min} \leq 0.1$ and, in the last bin, we let the accumulation over $1.0 \leq P_I \leq \infty$ represent the few respondents who would smuggle even if they *knew* they would be interdicted.

3. Minimum Chi-Square Estimation

Because the analytical solution to calculating the minimum value of X^2 based on differentiating by each parameter is very messy, we chose to search for the minimum manually. This was quite practical because computing X^2 is straightforward in Excel™. For the two parameters, α and $P_{\min}$, one can see that they are strongly correlated and search quickly for the minimum. The resulting best-fit values are good to four places after the decimal point. The X^2 value at this minimum point is a measure of the quality of fit.

C. STANDARD ERRORS

Common methods for estimating standard deviations and correlation coefficients require second derivatives of the likelihood function evaluated at the best-fit parameter values. Although these formulations are tractable, they might mask other important information such as how closely has the sample converged in a central limit theorem sense, or, equivalently, how much do cubic and higher order terms contribute to X^2 in a neighborhood about the best-fit values?

1. General Approach For One Parameter

For large sample sizes, consequences of the Central Limit Theorem state that minimum chi-square estimators will be unbiased and tend to follow a normal distribution. Also, the associated variances will be first-order efficient, i.e., equal, up to order $1/N$ terms, to what would be obtained by standard large-sample considerations involving second derivatives of the likelihood function. For modest sample sizes, however, the chi-square estimators will not conform with their limiting behavior—to some degree they will be biased, not precisely adhere to normal distributions, and tend to possess standard deviations that are over-inflated. Therefore, we adopted a method of estimating the standard errors that also provides information on the degree of noncompliance.

We retained the simplicity and convenience of the Excel™ minimization procedures directly in our standard error procedures. First, we combined groups of data with less than 4 samples so that all groups had at least 4 samples. Second, we determined the solutions to X^2 equal to $X^2_{\min} + 1$. Third, in our large-sample approximation, we based the standard error on the coefficient of the quadratic term derived from the increase in chi square about its minimum value.[1]

Furthermore, we were able to check whether X^2 within the near minimum region had converged to a pure quadratic as expected in our large sample procedure. We established a 5x5 array of neighboring values centered about the best estimate, made zero by subtracting the best estimate value from it and all surrounding values, and encircled by outer rings equated to one and two times the standard errors. Standard linear regression was then performed to determine to what degree the cubic and higher order terms (including cross terms) contribute to X^2, as measured by R^2. Note that the centering has eliminated the constant and linear terms.

---

1 For large samples, the Taylor series expansion involving powers of the minimum chi-square estimator is asymptotically equivalent to the more common approaches.

2. Fit 1: Fixed Exponent and Individual P_{min}

The above procedure was easy to implement to find P_{min} for each case given both the number of responses, N, and the common a priori value of $\alpha = 1.0$. Clearly, the convicted associate case has a very poor fit relative to the other cases.

Table B-1. Unit Exponent, Individual P_{min} and Uncertainties, and Quality of Fit

		Self			Associate		
Item	**Overall**	**Imprisoned**	**Convicted**	**Caught**	**Imprisoned**	**Convicted**	**Caught**
Exponent	1.0000	N/A	N/A	N/A	N/A	N/A	N/A
P_{min}	N/A	0.0202	0.0309	0.0402	0.0536	0.0671	0.0777
Std Error	N/A	0.0039	0.0044	0.0046	0.0051	0.0045	0.0040
Chi Square	8.5473	0.0476	0.2498	2.9203	1.1602	11.1307	4.1695
Chi Sq Probability	0.5755	0.9765	0.8826	0.2322	0.5599	0.0038	0.1243
R^2 (Quadratic and cubic fit)		0.99155	0.99984	0.99992	0.99992	0.99988	0.99957
(Cubic contribution)/(Quadratic)		-2.24%	-7.49%	-4.50%	2.00%	6.16%	14.12%

Here, each P_{min} was fit separately as the only parameter. Complications arise, however, when there are two correlated parameters.

D. STANDARD ERRORS FOR MULTIPLE PARMETERS

With two or more parameters to fit simultaneously, we must generalize the simple procedure given above for estimating the standard deviations.. The condition for X^2 to increase by 1.0 now defines an ellipsoid in parameter space centered on the best-fit values. Although it is easy to vary only one parameter deviation from its best fit value and find the points where X^2 increases by 1.0, these are points on a section through the general ellipsoid – *not* the best estimators of the standard error for that parameter. The best estimator is, rather, the extreme values of the ellipsoid projected onto the parameter axis. In other words, the standard error for a given parameter is the extreme value it can take on the unit ellipsoid *when all other parameters are allowed to vary freely.*

1. Fit 2: Individual Exponents and P_{min} for each Case.

We can illustrate how to readily obtain the standard errors and correlation coefficients by generalizing the simple procedure to the two-parameter fit. When we fit each case separately allowing both α and $P_{\min}$ to vary, the parameters proved to be highly correlated. Again, Excel™ can fit all three quadratic and four cubic terms about the best-fit values of the two parameters. Given the fitted quadratic coefficients, we can match those to known general form of the two-parameter normal distribution. Let $\xi_\alpha = \alpha - \overline{\alpha}$ and $\xi_p = P_{\min} - \overline{P}_{\min}$, the deviations from the best fit, then:

$$\Delta X^2(\xi_\alpha, \xi_p) = a_{2,0}\frac{\xi_\alpha^2}{\hat{\xi}_\alpha^2} + a_{1,1}\frac{\xi_\alpha}{\hat{\xi}_\alpha}\frac{\xi_p}{\hat{\xi}_p} + a_{0,2}\frac{\xi_p^2}{\hat{\xi}_p^2} = \frac{1}{1-r^2}\left(\frac{\xi_\alpha^2}{\sigma_\alpha^2} - 2r\frac{\xi_\alpha}{\sigma_\alpha}\frac{\xi_p}{\sigma_p} + \frac{\xi_p^2}{\sigma_p^2}\right)$$

where $\hat{\xi}_\alpha$ and $\hat{\xi}_p$ are the arbitrary scale factors used in the 5x5 target matrix that defines the X^2 values fit by regression to obtain $a_{2,0}, a_{1,1}$, and $a_{0,2}$. Now equating like powers of the ξ, because both parameters can vary independently, we obtain:

$$r = \frac{-a_{1,1}}{\sqrt{a_{2,0} \cdot a_{0,2}}} \quad ,$$

$$\sigma_\alpha = \frac{\hat{\xi}_\alpha}{\sqrt{a_{2,0}(1-r^2)}} \quad \text{, and}$$

$$\sigma_p = \frac{\hat{\xi}_p}{\sqrt{a_{0,2}(1-r^2)}} \quad .$$

As before, we can check the quality of the regression fit and the size of the cubic terms to estimate the convergence to the large N limit.

Table B-2 shows the results of fitting individual exponents and $P_{\min}$ values for each case. The exponents form a progression, but their uncertainties span a common value of −1.0. The $P_{\min}$ values also form a progression that we shall see is common to all of the other fits to the exponent. Most of the quality of fit estimates are good except that for convicted associate. Finally, the cubic is an excellent approximation to the deviations from minimum chi-square; cubic contributions are moderate to small, although we are not entirely in the large sample limit.

Table B-2. Best Fit Individual Exponents and $P_{\min}$, Uncertainties, and Quality of Fit

	Self			Associate		
Item	Imprisoned	Convicted	Caught	Imprisoned	Convicted	Caught
Exponent (X)	1.0600	1.0609	0.9860	1.1940	1.0970	0.9425
Exponent Std Error	0.2928	0.2284	0.1898	0.1951	0.1671	0.1334
P_{min} (Y)	0.0221	0.0330	0.0397	0.0590	0.0695	0.0766
Std Error	0.0099	0.0090	0.0085	0.0069	0.0057	0.0050
Correlation Coef.	0.9252	0.8765	0.8418	0.7400	0.6738	0.5585
Chi-Square	0.0175	0.1716	2.9095	0.1002	10.8358	3.9859
Chi-Sq Probability	0.8947	0.6787	0.0881	0.7516	0.0010	0.0459
R^2 for Chi-square fit	0.99867	0.99936	0.99959	0.99965	0.99965	0.99952
YYX/YY=	26.17%	16.90%	12.27%	4.02%	-0.97%	-5.30%
YYY/YY=	-12.55%	-7.13%	-4.39%	2.65%	7.53%	13.59%

2. Fit 3: Common Exponent but Individual $P_{\min}$ for each Case

In the final case, we increase the degrees of freedom by fitting a common exponent to five cases – excluding the deviant convicted associate case. We still fit individual $P_{\min}$ for each of the six cases with common exponent. Where we had a simple two-variable quadratic before, we now have, in principle, a six-parameter quadratic form. The quadratic expression surrounding the best fit values is defined by:

$$\vec{X}^T M^{-1} \vec{X}$$

where the vector is the exponent followed by five $P_{\min}$ values, M is the 6x6 covariance matrix, and the overall expression reduces to the desired quadratic form.

The covariance matrix for our fit is given by:

$$\begin{bmatrix} \sigma_\alpha^2 & r_1\sigma_\alpha\sigma_1 & r_2\sigma_\alpha\sigma_2 & \cdots & r_5\sigma_\alpha\sigma_5 \\ r_1\sigma_\alpha\sigma_1 & \sigma_1^2 & 0 & \cdots & 0 \\ r_2\sigma_\alpha\sigma_2 & 0 & \sigma_2^2 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & 0 \\ r_5\sigma_\alpha\sigma_5 & 0 & 0 & 0 & \sigma_5^2 \end{bmatrix}$$

where the numerical subscripts refer to the five different $P_{\min}$. To obtain the desired quadratic form, however, we must find the inverse of this matrix and expand the resulting quadratic form. With some effort, this gives the quadratic form of X^2 as the following:

$$\Delta X^2 = \frac{x_\alpha^2 - 2x_\alpha \sum_i r_i x_i - \sum_{i,j:i\neq j} r_i r_j x_i x_j + \sum_i x_i^2 (1 - \sum_j r_j^2 + r_i^2)}{1 - \sum_j r_j^2}$$

where $x_\alpha = \dfrac{\xi_\alpha}{\sigma_\alpha}$ and $x_i = \dfrac{\xi_i}{\sigma_i}$.

By varying x_α and x_i in pairs leaving all $x_j = 0$ for all $j \neq i$, we cause the third term in the numerator to vanish while leaving a two-variable quadratic form in x_α and x_i. Again equating corresponding coefficients we obtain:

$$\frac{-a_{1,1}}{2\sqrt{a_{2,0}a_{0,2}}} = \frac{r_i}{(1 - \sum_j r_j^2 + r_i^2)^{1/2}} \equiv \rho_i$$

where the a's are different for each pair indexed by i. This can be solved algebraically for the $\sum_j r_j^2 \equiv R$ yielding:

$$R = \frac{1}{1 + \left(\sum_i \frac{\rho_i^2}{1 - \rho_i^2} \right)^{-1}}$$

With these relationships, we can solve for the standard errors and the correlation coefficients:

$$r_i = \left(\frac{1 - R}{\frac{1}{\rho_i^2} - 1} \right)^{1/2},$$

$$\sigma_\alpha = \frac{\hat{\xi}_\alpha}{\sqrt{a_{2,0}}}\left(\frac{1}{\sqrt{1-R}}\right)^{1/2} \text{, and}$$

$$\sigma_i = \frac{\hat{\xi}_i}{\sqrt{a_{0,2,i}}}\left(1+\frac{r_i^2}{1-R}\right)^{1/2}.$$

Table B-3 summarizes the fit to this common exponent. Now the uncertainty ranges are smaller for the exponent although it still includes −1.0. The correlation coefficients are also smaller because the common exponent is not as free to vary. Finally, quality of fit is as good as for the other fits, and the cubic contributions are reduced.

Table B-3. Common Exponent, Individual $P_{\min}$, Uncertainties, and Quality of Fit

		Self			Associate		
Item	**Overall***	**Imprisoned**	**Convicted**	**Caught**	**Imprisoned**	**Convicted***	**Caught**
Exponent	1.0290	1.0290	1.0290	1.0290	1.0290	1.0290	1.0290
Exponent Std Error	0.0684	0.0684	0.0684	0.0684	0.0684	0.0684	0.0684
$P_{\min}$	N/A	0.0211	0.0319	0.0413	0.0544	0.0681	0.0783
$P_{\min}$ Std Error	N/A	0.0041	0.0048	0.0050	0.0053	0.0044	0.0040
Correlation Coefficient	N/A	0.3564	0.3350	0.3299	0.2403	N/A*	0.1891
Chi Square*	8.4348	0.0200	0.1929	2.9767	0.8576	10.9705	4.3876
Chi Square Probability	0.4910	0.9901	0.9081	0.2257	0.6513	0.0041	0.1115
R^2(quadratic and cubic)		0.9994	0.9998	0.9999	0.9999	0.9996	0.9997
Cubic contributions	YYX/YY =	12.79%	8.40%	5.84%	1.94%	N/A	-2.12%
	YYY/YY=	-14.22%	-7.76%	-3.49%	1.75%	9.84%	14.21%

* Convicted Associate was not included in the overall Chi Square fit.

APPENDIX C

ACRONYMS

APPENDIX C
ACRONYMS

ARIMA	Auto Regressive Integrated Moving Average
ARROBA	Unit of weight for coca leaves, equal to 25 lbs. (11.34 kg), often denoted as "@"
ATS	Amphetamine Type Stimulants
AWACS	Airborne Warning and Control System
C.HC1	Cocaine Hydrochloride
$C_{17}H_{21}NO^4$	Methylbenzoylepgonine
CADA	Cuerpo de Asistencia para el Desarrollo Alternativo
CAJ	Commission Andina de Juristas
CARGA	Unit of weight for coca leaves, equal to 100 lbs. (45.36 kg)
CD	Counterdrug
CNC	Crime and Narcotics Center
CNP	Colombian National Police
COCALERO	Coca grower
CORAH	Cultivo de la Coca en el Alto Huallaga
D&M	Detection and Monitoring
DCI	Director of Central Intelligence
DEA	U.S. Drug Enforcement Administration
DINANDRO	"Direccion Nacional de Drogas," PNP's anti-drug directorate
DoD	U.S. Department of Defense
DoS	U.S. Department of State
ELN	Ejercito de Liberacion Nacional, The National Liberation Army, a Colombian guerrilla group
ENACO	Empres Nacional de la Coca
FAP	Peruvian Air Force
FARC	Fuerzas Armada Revolucionarias de Colombia, the Revolutionary Armed Forces of Colombia, Colombia's largest guerrilla group
FBIS	Foreign Broadcast Information Service
FD/SD	Force-Down/Shoot-Down
FIRMA	Peruvian coca-processing/trafficking organization

GAO	U.S. General Accounting Office
GBR	Ground Based Radar
gm	Gram
GOC	Government of Colombia
GOP	Government of Peru
ha	Hectares
HCl	Cocaine Hydrochloride
IDA	Institute for Defense Analyses
INADE	Institute for National Development
INCSR	International Narcotics Control Strategy Report, issued annually by INL
INL	Bureau of International Narcotics and Law Enforcement Affairs, U.S. Department of State
kg	Kilograms
MIS	Management Information System
MRTA	Movimiento Revolucionario de Turpac Amaru, the Turpac Amau guerrilla movement in Peru
MT	Metric Ton
NAS	Narcotics Affairs Section
NNICC	National Narcotics Intelligence Consumers Committee
PCB or PBC	"Pasta Basica de Cocaina," paste and base of varying purities
PEAH	Proyecto Especial Upper Huallaga
PNP	Peruvian National Police
SBCL	SmithKline Beecham Clinical Laboratories
SIN	National Intelligence Service
SJ	"Support Justice" operations directed by USSOUTHCOM
SL	Sendero Lumioso, or "Shining Path" guerrilla group
SLB	Santa Lucia Base
SOUTHCOM	Southern Command
STRIDE	System to Retrieve Information from Drug Evidence
SZ	Source Zone
TAT	Tactical Analysis Team, within U.S. Embassies.
TZ	Transit Zone
UHV	Upper Huallaga Valley
UNDCP	United Nations Drug Control Program

UNODCCP	United Nations Office for Drug Control and Crime Prevention
USAID	United States Agency for International Development
USCG	United States Coast Guard
USCS	United States Customs Service
USG	United States Government
USSOUTHCOM	United States Southern Command, DOD's principal liason with Latin American governments for implementing security assistance programs
WOD	War on Drugs

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE April 2000	3. REPORT TYPE AND DATES COVERED Final: 1989 - 1999

4. TITLE AND SUBTITLE Deterrence Effects and Peru's Force-Down/Shoot-Down Policy: Lessons Learned for Counter-Cocaine Interdiction Operations	5. FUNDING NUMBERS DASW01-98-C-0067, OUSD(A) BB-9-1494
6. AUTHOR(s) Dr. Robert W. Anthony, Dr. Barry D. Crane, Mr. Stephen F. Hanson	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Institute for Defense Analyses 1801 N. Beauregard St. Alexandria, VA 22311	8. PERFORMING ORGANIZATION REPORT NUMBER IDA Paper P-3472
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Mr. Lennard J. Wolfson Special Assistant for Intelligence and Technology, Office of the Undersecretary of Defense/Policy, Drug Enforcement Policy and Support The Pentagon, Rm. 2E549, Washington, DC	10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited. Directorate for Freedom of Information and Security Review, 21 June 2000.	12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

This paper analyzes the counter-cocaine air interdiction campaign against trafficker flights from Peru to Colombia from 1989 through 1997. We show that once the rate of interdiction of trafficker flights exceeds a threshold, which depends upon the severity of consequences of being interdicted, other pilots are strongly deterred. A modest Peruvian Air Force with U.S. intelligence, detection, and monitoring support interdicting only 3 percent of potential flights under a lethal threat thwarted 80 to 90 percent of potential flights. Immediately following such action in 1995, Peruvian coca prices collapsed. By 1999 farmers abandoned 66 percent of their fields, and residual cultivation concentrated into smaller areas. As Colombians have attempted to replace lost sources, they have further concentrated cultivation in their southwest, creating another lucrative transport interdiction target. We also show that the cocaine market structure amplifies source-zone price increases by a factor of 100 as the product reaches U.S. streets 4 to 5 months later. Consequently, successful source-zone interdiction operations immediately damage source-zone coca markets and later raise street prices, lower street purity of cocaine, and correlate with significant

14. SUBJECT TERMS Counterdrug interdiction; cocaine; deterrence; cocaine market structure; cocaine cultivation; Peru; interdiction air operations; cocaine source-zone prices	15. NUMBER OF PAGES 302
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited